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WM. SPRARAGEN
Editor

AMERICAN WELDING SOCIETY

EDITORIAL AND BUSINESS OFFICES

33 West 39th St.
New York, N. Y.

FALL MEETING

The fall meeting of the American Welding Society will be held in Boston during the week of September 21.

As in previous years the meeting will be arranged in conjunction with a welding exhibition held jointly with the American Society for Steel Treating. A number of other societies are planning to hold meetings in Boston during this week.

A large local committee has been working in close cooperation with the national exposition committee in arranging for all details to make this meeting the most successful fall meeting ever held by the Society.

Ladies' entertainment will be featured as will, also, the annual dinner to which are expected more than six hundred people.

The national Meetings and Papers Committee have already secured some of the most outstanding papers of the year for presentation at this meeting.

The final report of the Structural Steel Welding Committee, in which some forty fabricating shops and over twenty universities participated, will be featured at the meeting.

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JOURNAL OF THE AMERICAN WELDING SOCIETY

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ACTIVITIES

AMERICAN WELDING SOCIETY

Report of the President for the year ending March 31, 1931 (presented in abstract at the Annual Meeting of the Society, April 22, 1931).

The following report is a brief review of the American Welding Society affairs in which it is the aim of your President to outline the high lights of Society activities for the calendar year 1930, which is the twelfth year of the Society's existence.

Most of the matters touched on in this report are covered in detail by the annual reports of the chairmen of the several standing committees and which are available for your information and will appear in the course of the coming year in your Journal.

For the purpose of paralleling past annual reports, the usual sequence of committee business will be followed herein.

MEMBERSHIP—During the year just closed, the Membership Committee did not inaugurate special membership campaigns to secure new members, though one or two sections did make such drives. The reason given by the Membership Committee for not making more concerted effort is, that it was felt to be an inopportune time for such campaigns because of the general business depression. Moreover, the Membership Committee felt it desirable to wait upon the final clarification and classification of the various grades of membership in the Society. This was called to the attention of the Executive Committee and the Committee on the Revision of By-Laws, and after due consideration, the Executive Committee expressed itself as feeling that it would be best to wait until there is an upturn in business activity before making any definite changes.

Special attention is called to the fact that even in time of depression, the Society membership increased by 81 members, bringing the total membership as of April 1, 1931, to 1424, the highest number in the history of the Society.

FINANCE—The total receipts during the Society year ending March 31, 1931, were $40,677.34. The corresponding disbursements were $43,268.92. While the receipts were $2,502.90 greater than the receipts for the previous year, the disbursements were $7,045.28 greater than the preceding year. This shows a reduction of cash balance of $2,591.58. The reduction of cash balance is offset by printing cost of $1,729.46 more than for the year 1929. This figure includes 13 issues of THE JOURNAL instead of 12 (no reason given by auditors for including 13 issues). We also have on hand $2,500 worth of salable printing matter, as against $500 worth of like matter on March 31, 1930 (an increase of $2,000).

Cash on hand March 31, 1931, $2,189.77.
Invested in bonds, $5,269.50.
Present worth of Society, $13,517.65.

A detailed financial statement will be presented to the Board of Directors at this annual meeting, and will also be published in the Society Journal.

HEADQUARTERS—Early in the fall of 1930, the secretary was advised that it would be necessary for the Society to vacate its quarters on the sixteenth floor of the Engineering Societies' Building, as the space was required by one of the founder societies. This necessitated quick action in order to avoid being compelled to leave the Engineering Societies' Building. A small committee was appointed to confer with the proper parties, and arrangements were finally closed for a new space on the fourteenth floor, where your Society headquarters are now located in a somewhat larger and more attractive space and at a lower rental than the space occupied until September, 1930.

JOURNAL—One of the most interesting developments in the activities of the Meetings and Papers Committee during the past year was the change in the size of THE JOURNAL to the standard 9 x 12 in. size. This change was brought about for several reasons, the most important being the possibilities of increasing the advertising and circulation of THE JOURNAL. The new size, reducing the number of pages, will avoid the necessity of binding each volume in two sections. To encourage increased circulation of THE JOURNAL, the Executive Committee has changed the subscription price from $10 to $5.

Although the publication of THE JOURNAL during the year 1930 has continued to be profitable, nevertheless the margin of profit has been materially reduced. The large increase in the number of pages and in the circulation of THE JOURNAL, accounts for the greater portion of the reduction in margin of profit.

The total number of printed pages and its comparison with the previous year are given below:

	1929	1930
Editorial and circular	202	238
Technical	862	1,075
Advertising	192	211
	1,256	1,524

This shows an increase of 21 per cent in the size of THE JOURNAL.

Special attention was given during the year to balancing THE JOURNAL between the various welding processes.

MEETINGS—The annual meeting was held as usual in New York in April, 1930. The registered attendance at the meeting was 214. The number of technical sessions was 5. The Board of Directors' meeting was held in the evening of Wednesday, April 23. The annual dinner, a stag affair, was held in the evening of Thursday, April 24. There were, as usual, a number of committee meetings held on the several days.

FALL MEETING—The 1930 fall meeting of the Society was held in Chicago, September 22 to 26, and as in the past three years, an exposition was arranged jointly with the American Society for Steel Treating. Six technical sessions were held during the meeting, at which a total of 22 technical papers were presented.

At this, the Ninth Fall Meeting and Exposition of the Society, the official registration totaled approximately 400, which was about 100 more than at the previous fall meeting. The exhibitors numbered 25 and occupied space of about 6000 sq. ft., as against 30 exhibitors in 1929 occupying space of about 11,000 sq. ft. The difference in this space was due to the fact that the exposition was held in a hotel and the space was a great deal more restricted than in the Convention Hall at Cleveland.

The financial returns to the Society from the 1930 exposition amounted to $854.06 as against $1,003.12 from

Class		Membership, March 31 1930	1931
(A)	Sustaining members	44	40
(B)	Members	498	443
(C)	Associate members	476	615
(D)	Operating members	279	273
(E)	Honorary members	3	3
(F)	Student members	43	50
	Total	1,343	1,424

the 1929 exposition. The difference in receipts was due also to the smaller amount of space permitted us at the 1930 meeting. The actual cost to the Society of promoting the 1930 meeting was $373.68. The cost of promoting the 1929 meeting was $393. This is rather a good showing, considering that at the 1930 meeting our membership totaled 350 more than in 1929, and these additional members had to be taken care of with correspondence and various publications as issued by the Society.

The Annual Dinner was attended by over 200 ladies and gentlemen, which is comparable to past dinners. One of the outstanding features of the dinner was the fact that the Chicago Section was able to show a profit of nearly $200, which was turned over to headquarters.

The report of the ASST on the general attendance indicated that over 50,000 people visited the exposition. This compares favorably with the number of visitors at previous exhibits.

SECTIONS—The number of local sections has not changed during the past year, and while there has been more activity in some localities than in others, the general condition of the several sections is apparently healthy, with the possible exception of one, and it is planned to direct special attention to this one during the coming year.

The Meetings and Papers Committee has on several occasions assisted the local sections in arranging suitable programs and symposiums. The most notable section activity during the year was a meeting put on by the New York Section in the interests of structural welding, which will be referred to later on in this report under a different heading.

SOCIETY COMMITTEES — During the past year the Committee on Nomenclature, Definitions and Symbols, having completed its work, was discharged with thanks, but immediately a new committee was appointed for the purpose of making additions and revisions to the Society's standard on Nomenclature, Definitions and Symbols. The following new committees have been appointed to cover assignments, as listed:

I. Sub-Committees of Committee on Building Codes, to consider—
   (1) Resistance Welding,
   (2) Specifications for reconditioning surface defects in rolled steel by means of chipping, welding and grinding;
   (3) Proposed Detroit Building Code,
   (4) Proposed Chicago Building Code.

II. Committee on Revision of Nomenclature, Definitions and Symbols (mentioned above), and sub-committee to cover Standardizing filing systems and to prepare classification system for indexing and filing information on welding,

III. Special Committee to confer with Steam Boat Inspection Service, resulting in the appointment of a representative of the Steam Boat Inspection Service on your Committee on Welding in Marine Construction,

Enlargement of Committee on Welding and Marine Construction, by appointment of representatives from the Boiler Code Committee of the A.S.M.E., Hartford Steam Boiler and Insurance Company, Resistance and Thermit Welding Industries and the appointment of two sub-committees, one dealing with hull construction and the other with Marine Boilers.

IV. Committee on the use of Welded Steel Parts for Construction of Machinery for the purpose of producing specifications covering fundamentals of design for conversion of machine tool and electrical equipment, as well as other mechanical parts now made from castings to welded steel,

V. Committee on revision of Arc Welding Manual. This manual to be brought up to date as the supply of the first edition is about exhausted,

VI. Committee on Society Incorporation. Resolution to be presented to you at this Annual Meeting,

VII. Committee to render assistance in determining power requirements for operating resistance welding equipment. This committee instructed to ascertain from public utility companies and manufacturers of resistance welding equipment, the extent of their willingness to cooperate by the furnishing of both data and funds to enable the committee to make an intelligent study of ways and means of rendering assistance to public utility companies,

VIII. Committee on Standards prescribing requisites of a Welding School Graduate,

IX. Committee to confer with Board of Fire Underwriters regarding discrimination against use of welding steel pipe for underground fire line work in certain States,

X. Committee to confer with A.S.M.E. Boiler Code Executive Committee and the Compressed Gas Manufacturers Association on the proposed classification of Unfired Pressure Vessels,

XI. Committee on Welding Exhibit, World's Fair Centennial Celebration at Chicago.

During the year just closed your Committee on Revision of By-Laws prepared proposed revisions covering,

(1) Stipulation for definite number of directors on Board of Directors (required for incorporating the Society),

(2) Provision for Committee on Code of Principles of Conduct.

These proposed revisions were put in proper form, circulated throughout the membership, voted upon and adopted.

Your Committee on Building Codes has made the following very creditable showing during the period covered by this report:

In the fall of 1930 a second edition of the Society's Code 1, Part A, was published as the "Edition of 1930." This document covers "Fusion Welding and Gas Cutting in Building Construction." Part A applies to Structural Steel. The edition of 1930 includes an appendix whose use obviated the necessity of consulting certain other publications which had been cited in the first (1928) edition. It also clarifies three paragraphs, but does not make any material change from the earlier edition. An issue of 10,000 copies was printed, of which 8000 have already been distributed.

Over 100 cities in the United States now permit welding to be used in building construction. In some cases the codes adopted are identical with that issued by the American Welding Society. In no case is there any important difference. New Orleans is the most recent city to have adopted the Society's code. The committee has cooperated with local groups, notably in Detroit and Chicago, where code revision that will permit welding is still pending. In New York City a representative of the Society is serving on an Advisory Committee which has prepared satisfactory rules for the use of welding in building construction, but these have not yet been officially acted upon.

In conjunction with the New York Section of the Society, a symposium was held November 18, 1930, on "Why Structural Welding Should Be Recognized by the Building Department." Discussion was secured from prominent representatives of all interested bodies. An attendance of nearly 1000 was reported. A resolution was passed urging the adoption of the Society's code by the New York authorities.

Statistics for buildings and bridges constructed in North America during the past year have been secured which indicates that over 25,000 tons of structural steel were fabricated or erected with the aid of welding.

Two new sub-committees have been organized and are now engaged in the preparation of codes for:

1. Welding building parts by a resistance process,
2. Conditioning fully rolled structural steel by means of welding.

Questions regarding the use of welding in reinforced and new bridge structures have been referred to the committee, and it is expected that a sub-committee will be appointed to cover these matters by the preparation of a code for the welding of bridges and similar structures which involve variable stresses and impact.

The new Committee on Revision of Nomenclature, Definitions and Symbols reports that it has held one meeting and that work has started on revision. It is also reported that the ASA has requested through its representative on the Welding Society's Nomenclature Committee approval of a glossary of electrical terms and definitions used in the electrical industry and made to conform to the American Welding Society's nomenclature covering electric welding.

It is also pointed out that official action is desired by our Society to have its nomenclature, definitions and symbols approved by the ASA, thus giving them a legal standing.

A report from the chairman of the Committee on Welding and Marine Construction indicates that the two sub-committees, namely, Welding on Marine Boilers and Welding in Hull Construction, have been outlined and consist in the preparation of American Welding Society Codes.

It was further decided that the Boiler Code Committee would prepare two independent codes, one for new construction and one for repair to boilers, while the sub-committee on Hull Construction will prepare one code.

In the preparation of these codes, the committee deemed it desirable to secure the cooperation and indorsement of all interested in the several fields, and while it is not expected that the Steam Boat Inspection Service, the American Bureau of Shipping and other regulatory bodies will in all cases accept the Welding Society's codes in their entirety, nevertheless these codes will form a fundamental basis for their welding rules and regulations.

The committee on the Revision of Arc Welding Manual reports through its chairman that a thorough revision of the present edition of the *Arc Welding Manual* and the literature

(*Continued on page* 47)

Thermit Welding and the Steel Mill

By J. H. DEPPELER

✦ This paper was presented at the Annual Meeting of the American Welding Society, by J. H. Deppeler, Chief Engineer of the Metal and Thermit Corporation.

MOST of the members of the American Welding Society are familiar with the basic principles of Thermit Welding, but in a paper of this kind it seems advisable to present some of the basic facts for the benefit of those who are not familiar with the process.

About thirty years ago a German scientist, Prof. Dr. Hans Goldschmidt, made an important discovery upon which the whole science of alumino-thermics depends. For many years the fact that aluminum had a greater affinity for oxygen than any other element had been well known and was the basis of the method of the reduction or deoxidation of most of the metallic ores and oxides. Very early inventors used this process of aluminum reduction in the actual manufacture of rarer metals. In their processes, the simple substitution of aluminum for carbon as the reducing agent was the accepted practice. The carbon required the application of considerable external heat to cause it to react with the oxides, whereas the aluminum because of its greater affinity for oxygen reacted much more actively and required little or no external heat. The reducing agent (aluminum) was mixed with the oxide in empirical proportions based on the known chemical reaction.

The contribution by Dr. Goldschmidt was really the discovery that if a mixture of metallic oxide and finely divided aluminum were ignited in one spot the reaction of this spot would furnish sufficient heat for the propagation of the reaction throughout the entire mass until the contents of the crucible were converted into a molten mass of metal and aluminum oxide slag. He also discovered that this reaction would in most cases pro-

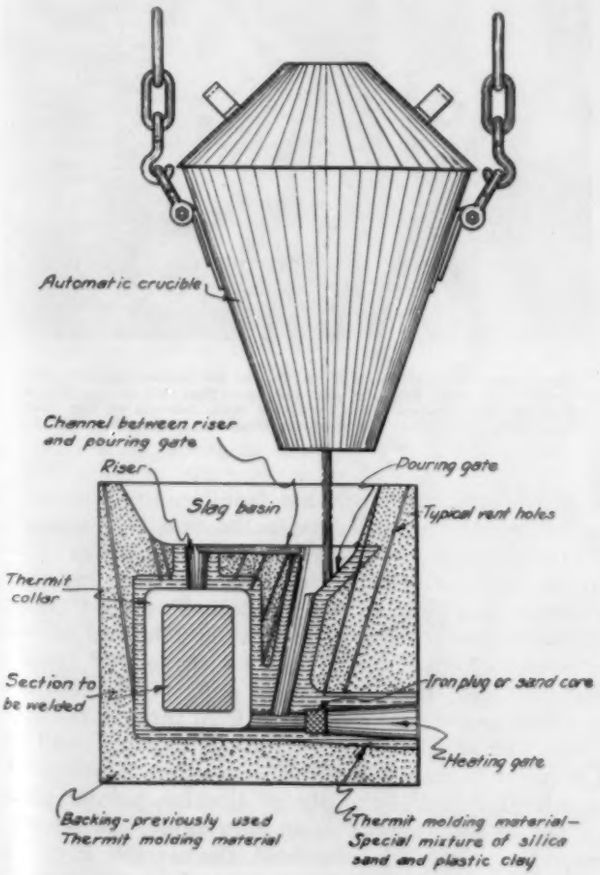


Fig. 1—Diagram Showing Method of Pouring and Detail of Mold for Thermit Welding

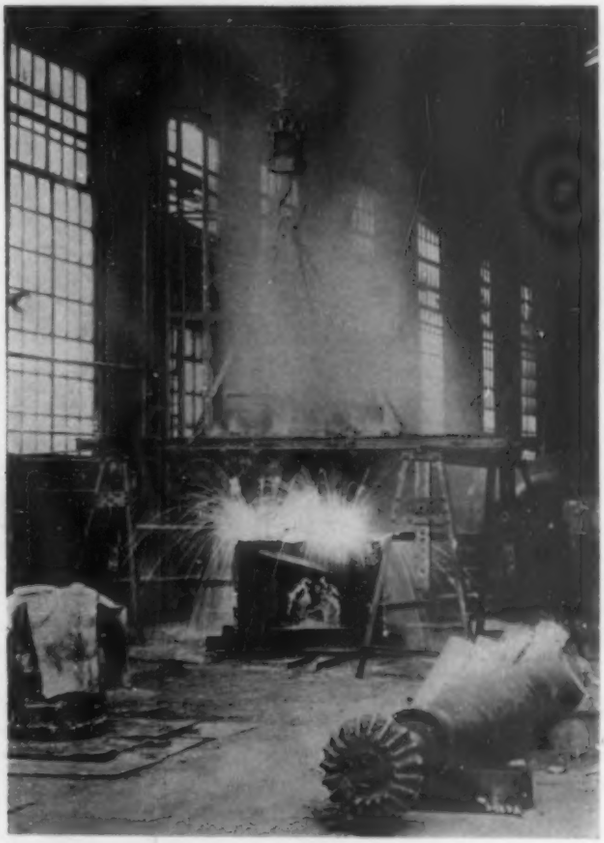


Fig. 2—Corner of a Steel Mill Reclamation Department Showing a Thermit Reaction in Progress. On the Left Is a Wabbler End of a Roll Ready for Repair, the Roll Itself Being Hidden in a Special Pit Provided in the Floor. The Mold for Another Large Weld May Be Seen in the Background

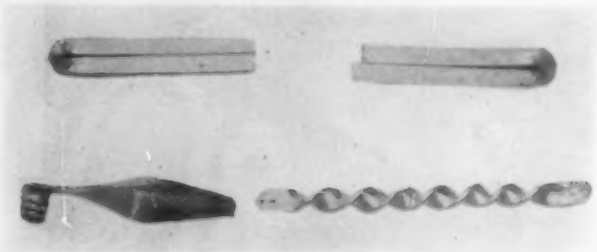


Fig. 3—The Two Bend Test Specimens Shown Here Were Taken from Welds in 10" x 10" Sections. The Bend Occurs Right at the Weld and the Specimens Were Bent "Flat" Without Even Roughening the Extreme Fibers. The Other Two Specimens Are Made of Thermit Steel Only

ceed in a cold mixture of the oxide and aluminum at a rate which would make possible the production of any quantity up to a ton or more of material in a single reaction lasting approximately thirty seconds.

The Thermit Welding Process depends principally on the alumino-thermic reduction of iron oxide. The oxide which is generally used is Fe_3O_4 in flake form, which is exceedingly important in increasing the speed

Fig. 4—Hundreds of Shafts Like This Have Been Welded Without a Single Failure. All Excess Metal Is Usually Machined Off, Making the Section at the Weld the Same as the Original Section

of the reaction. The physical size of the oxide flakes and the percentage of fines included in the mixture have also considerable effect on the time of reaction and the resultant heat. The time of reaction is also controlled by the addition of metallic elements to the Thermit mixture, which can be either in the form of a Thermit mixture of that metal or particles of the metallic element. In designing Thermit mixtures for use in welding, we have at our disposal many variables so that it is possible to control very definitely not only the speed and temperature of the reaction but the chemical analysis of the resultant steel, and thus to predict the physical properties of the resultant weld metal.

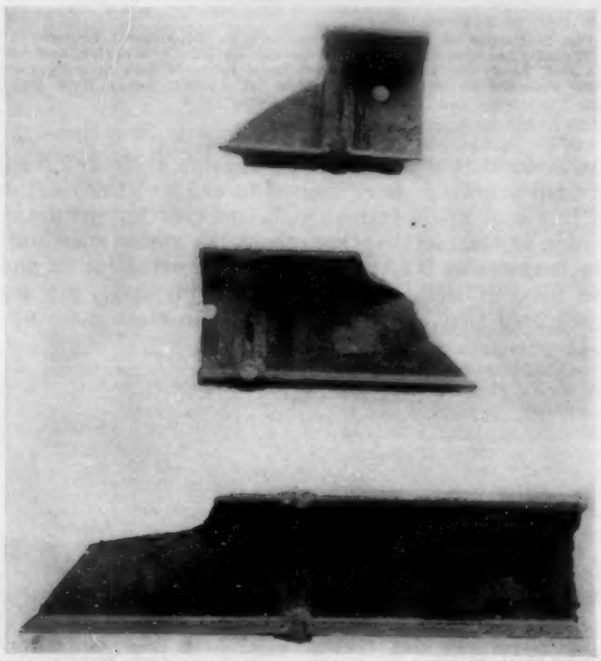
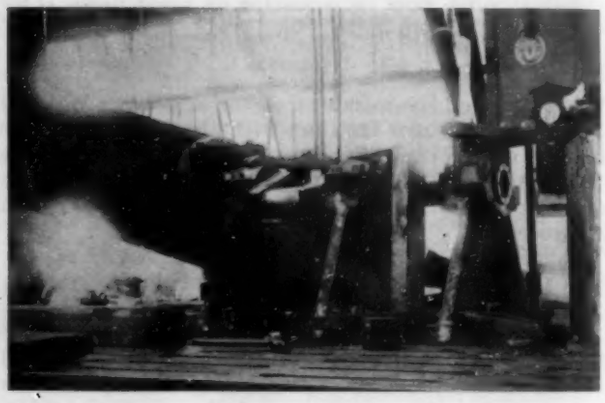
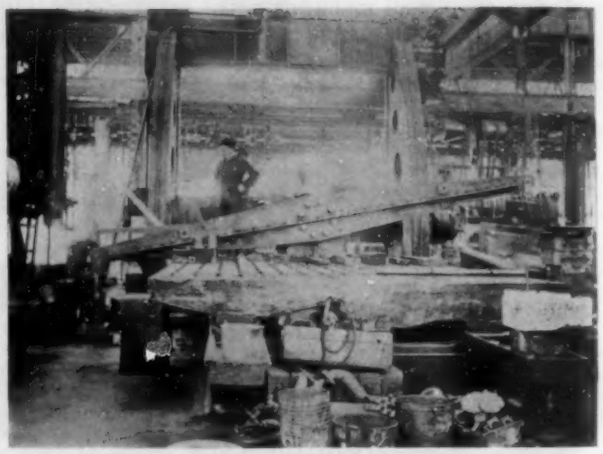


Fig. 5—Thermit Rail Welds Tested Under a Drop. Fractures so Far Away Are Proofs That There Is No Lack of Strength in or Near the Weld

The temperature of the steel resulting from the Thermit reaction is approximately double the temperature of ordinary molten steel; upon this superheat, the ability to make welds depends. This statement will probably be a little clearer after considering the method of making a Thermit weld (see Fig. 1). In a general way, this welding process is exceedingly simple as it requires no manual dexterity on the part of the operator, all that is required being the following of simple instructions. At the risk of a repetition of a procedure





Figs. 6 and 7—Final Stages of the Test of the Submarine E-2 Crankshaft. Note the Test Rig and the Fact That All of the Bearing Brackets Had Broken. The Unwelded Main Journal at This Stage Was Eliminated from the Test by Blocking Under the First Pin

with which many of you are familiar, I will outline in a few words the procedure in the case of a repair by Thermit Welding. The first thing required is to line up the parts and then to cut a parallel sided gap at the fracture, the width of the gap depending upon the size of the section. Around the break or joint is then built a refractory mold which provides an annular space at the fracture. The part is then preheated by means of kerosene and air blown into the mold through the opening, which simultaneously dries out the mold and heats the parts to a red heat. The reaction is started by means of a small quantity of ignition powder placed on top of the Thermit in an appropriate crucible and, when the reaction is completed, the crucible is tapped, allowing the resultant Thermit steel to run into the mold. This steel, having 100 per cent superheat and

held in place between and around the ends of the parts to be welded, will obviously give up its superheat to these parts, fusing and solidifying them together. With weld metal of good physical properties, sound and close-grained, and with the shrinkage properly allowed for, the results are most dependable. The important thing, therefore, then becomes the quality of the Thermit

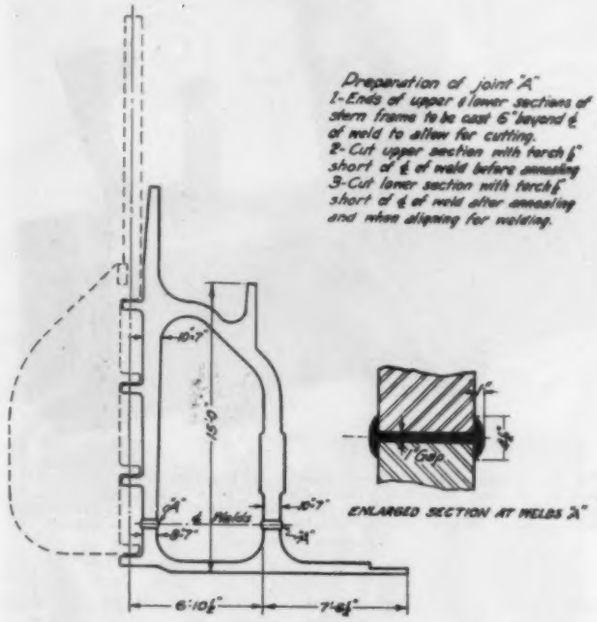

Preparation of joint "A"
1-Ends of upper & lower sections of stern frame to be cast 6" beyond ℄ of weld to allow for cutting.
2-Cut upper section with torch 6" short of ℄ of weld before annealing
3-Cut lower section with torch 6" short of ℄ of weld after annealing and when aligning for welding.
1" Gap
ENLARGED SECTION AT WELDS "A"

Fig. 8—New Stern Frame of Coast Guard Cutter "Northland," Showing Thermit Welds

steel itself and a brief review of the important things in the Thermit welding operation, upon which so much depends if sound welds are expected, is important.

The first question that generally comes up in considering the quality of Thermit steel is, how can such a cast steel possibly compare in strength with forged steel and will not the strength of the welded part be simply that of the cast steel in the weld and not that of the original forging? This is an exceedingly important question because if the Thermit weld is considered as having only the strength of cast steel, its application in steel mills is very limited. As a matter of fact, this is not the case as has been proven many times in tests and in actual practice. In a large number of tests, forgings that have been Thermit welded and tested to destruction will just as often fail completely outside of the welded area as they will in the weld or in the metal adjacent to the weld. We can account for this by theoretical deductions. Steel, as cast, differs from forged or worked steel not in its chemical composition but only physically. This physical difference lies largely in the weakness of the grain boundary. Commercial cast steel on solidifying throws out to the grain boundaries a large number of impurities which form part of the cementing medium between the grains, and make this weaker than the grains themselves. For this reason, the fractures of cast steel are usually intergranular. Forging, rolling or otherwise working these grains distorts them so that this grain boundary no longer is of importance, the strength of the piece being that of the material itself and not that of the weaker grain boundary. Thermit steels are produced by the reduction of a very pure iron oxide by an almost perfectly pure aluminum. Therefore, although cast, because they are relatively pure materials, a resultant steel similar to forged steel is produced without the necessity of refinement by working. Invariably the fractures on Thermit steel are through the grains and not, as in the case of most cast steels, along the grain boundaries so that the Thermit steel has all the properties of the forged steel except its appearance under the microscope. Whether this is the explanation or not, it is a fact that in every test and by actual service Thermit steels compare very favorably with the physical properties of the highest grade forgings.

This comparison was first brought out prominently during the war when a large company on account of its familiarity with the Thermit welding process asked the approval of Lloyds' Register of Shipping of the use of Thermit welding for the manufacture of stern frames for ships. This approval was readily given in the case of cast steel frames but withheld in the case of forged steel frames. This refusal was based on the idea that if a customer was willing to pay the extra cost of a forged steel frame, it would be unfair to furnish him a forged steel frame with cast steel welds, on the assumption that such a frame would be no stronger than the cheaper cast steel frame of similar design. Naturally, this contention resulted in a long series of tests because years of experience in the welding of forgings and particularly the welding of hundreds of heavy crankshafts without failure led to the belief that Thermit steel could not be judged directly from the foundrymen's experience. Very elaborate tests resulted, which consisted in the making of a large number of welds on 10 in. x 10 in. sections of forged steel approved by Lloyds, some of the welds being between sections with free ends and others between sections not free to move. The results of these tests are all available but the impact tests are probably the most interesting. These impact tests with the very excellent tensile and ductility showings resulted in the approval

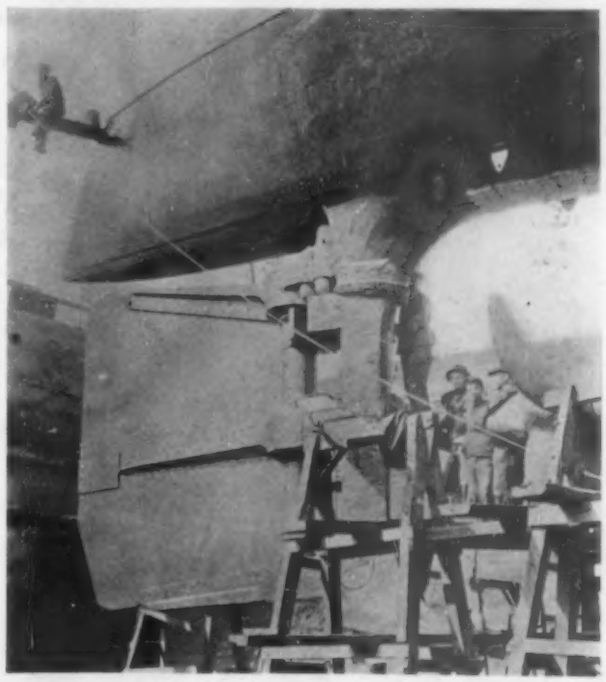


Fig. 9—Typical Stern Frame Repair. It Can Be Easily Seen How Welds of This Kind Are Not Only Useful in the Repair of Broken Frames but Also in Simplifying the Construction of new Frames

by Lloyds of the Thermit welding of forged steel frames. Two 10 in. square pieces of the Lloyds' steel, each about 3 ft. long, were Thermit welded end to end and, after welding, the piece was not annealed nor was any work done on it except that the excess metal at the weld was machined off. The resulting specimen, 6 ft. 3 in. long with the weld at the mid-point, was symmetrically supported horizontally on 5 ft. centers and a 3290 pound pear-shaped weight was dropped directly on the weld from a height of 18 ft. Progressively in nine drops, the middle of the test piece was deflected downwards 1 7/32 in. without any signs of distress. It was then turned over 180 deg. on the assumption that it could be rather easily broken if bent back again. The drop testing continued until after six more drops the piece had been practically straightened out (see Table A). After this, Lloyds' engineer suggested that the weld be sectioned and examined internally rather than to continue the impact testing which might have been prolonged.

A test of a very practical nature was run a few years prior to this by the Navy Department. A crankshaft of the Submarine E-2 was welded and tested to destruction at the Brooklyn Navy Yard. This was a two-throw shaft with hollow journals and with a flange on each end; the break was in the main journal next to the flange. The material was a high grade molybdenum steel. All excess metal was machined from both inside and outside the shaft after the weld was completed, and the piece was supported on special brackets bolted to a 40-ton planer bed with a lever bolted to the flange of the shaft with the weight pan on one end and a hydraulic jack on the other. The shaft was prevented

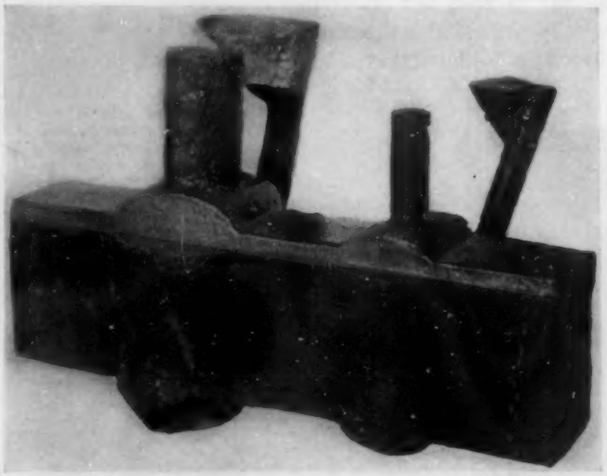


Fig. 11—Comparison of the Amounts of Thermit Used in the Old and in the New Practice. This Reduction Greatly Reduced the Cost of the Welding Operation, but the Reason for It Was Primarily the Improvement of the Internal Quality of the Weld as the Result of Extensive Research

from turning by blocking under the second pin so that the test was made of both the welded main journal and the unwelded main journal. The strength of the unwelded main journal had previously been proven when the shaft was originally broken. Early in the test, the shaft was gradually twisted and failed in an axial crack in the unwelded main journal. The orders being to test the weld to destruction, the first pin journal was blocked to the planer bed so that all the torsion was applied to the welded journal. When the heavy cast steel bearing brackets broke one by one and the 1¼ in. bolts holding the brackets to the planer bed began to

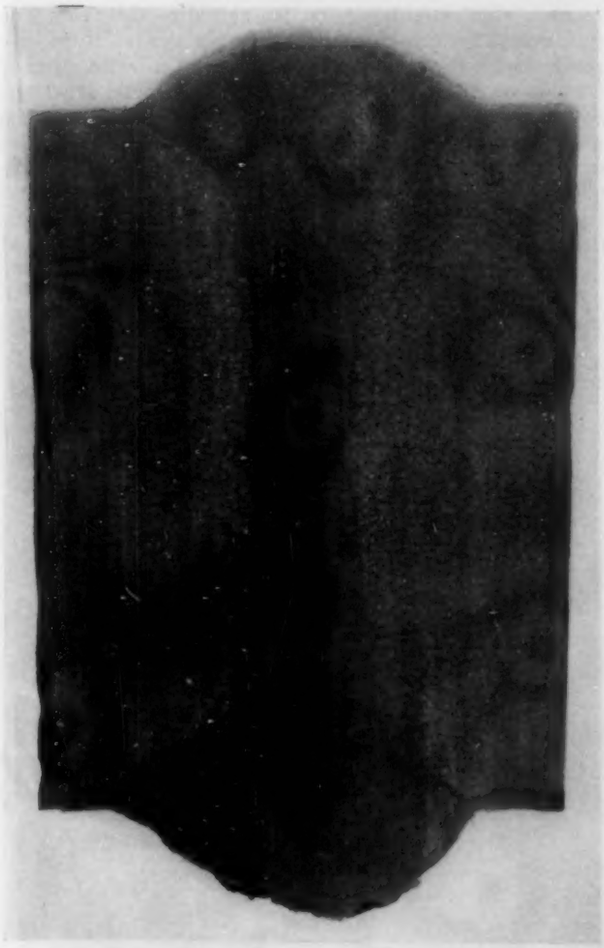


Fig. 10—Section Through a Thermit Weld, Polished and Etched. The Original Opening Between the Pieces Had Parallel Sides; the Curved Lines Are the Result of the Fusion. The Weld Is All Made at One Time and, Therefore, Locked-up Stresses Are Reduced to a Minimum

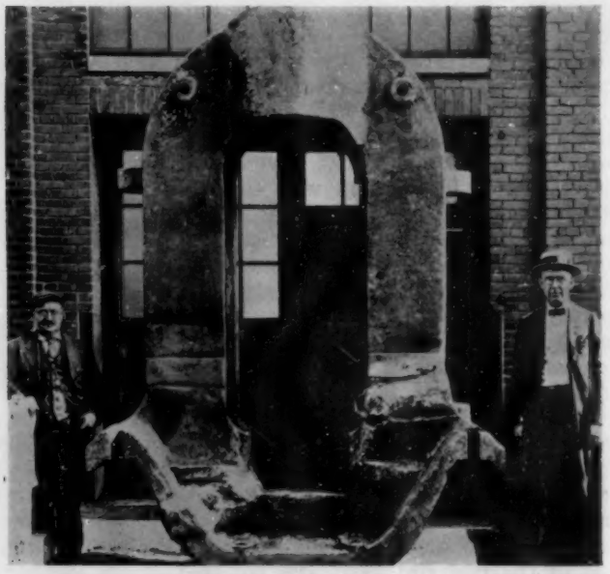


Fig. 12—Two Breaks in Cast Iron Mill Housing. This Welding Process Lends Itself to Cast Iron Repairs as Well as Steel. This Housing Is Typical of Many Steel Housings Similarly Welded

TABLE A.—RESULTS OF DROP TEST ON 10″ × 10″ SECTIONS OF FORGED STEEL

Drop no.	Height ft.	Deflection in.
1	9	0
2	12	1/16
3	15	1/16
4	18	1/32
5	18	1/32
6	18	3/32
7	18	3/32
8	18	1 3/32
9	18	1 1/32
Billet turned over 180°		
10	18	1/16
11	18	1/32
12	18	1/16
13	18	1/32
14	18	1 1/16
15	18	1 1/8

stretch, the test was stopped for fear of seriously damaging the planer bed; the welded journal had shown no sign of failure.

Since the approval of Thermit Welding by the various shipping bureaus, hundreds of stern frames of steamers have been welded and, although there have been one or two failures, the breaks have never been closer than three feet from the weld. This may not be a true test of the comparative strength of Thermit steel and forged steels, because the excess metal is seldom machined off, but it does indicate that the metal next to the weld is not harmed to any appreciable extent by re-crystallization or otherwise.

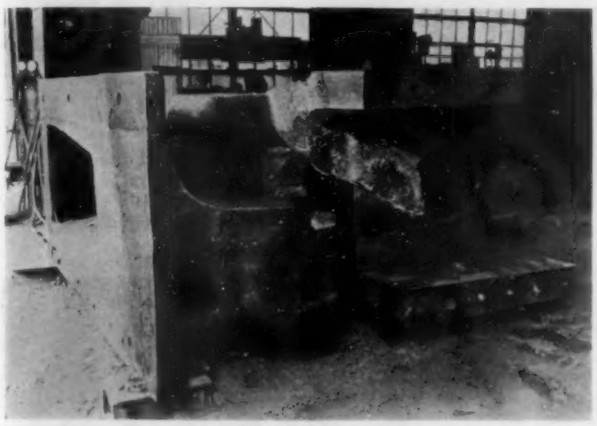


Fig. 13—Weld in Cast Steel Frame of a Large Machine

Fig. 14—Three Welds in the Frame of a Cinder Ladle Carriage

Although many other tests, both laboratory and practical, could be described, these will serve to show that Thermit steels are equal to most forged steels as far as fatigue and impact values are concerned. The other physical properties are easily controlled between certain wide limits in the manufacture of the Thermit mixtures. The possibility of the introduction of practically all metallic elements into the weld metal in any desired proportions allows for almost unlimited variation in the physical properties of the resultant steel. The various elements can be introduced either by means of metallic pieces, which would be melted during the reaction, or may be introduced in the form of Thermits—namely, combinations of the oxide of the metallic element with aluminum (see Table B). A long series of experiments with the efficiencies in reaction of the various metallic oxides, which determined the combination of Thermits which will definitely produce a steel of a given analysis, is well known. By such means, the tensile strength, ductility and hardness of the resultant steel is easily controlled. The tensile strength can be varied from 50,000 lb. per square inch to 110,000 lb. per square inch with the corresponding

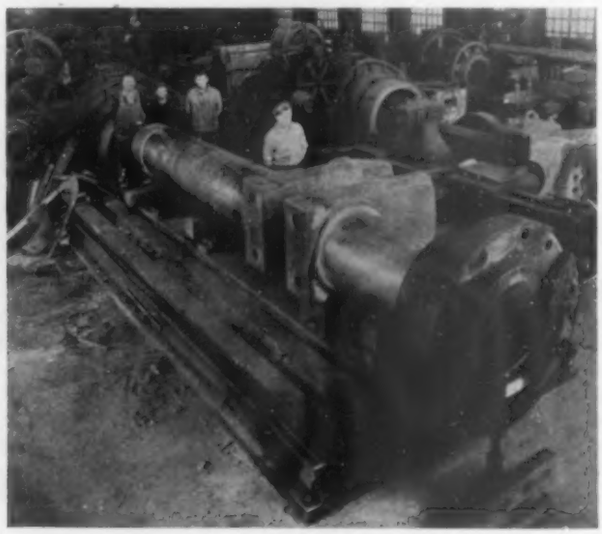


Fig. 15—Reclamation Department with a Thermit Weld in the Web of a 28″ Diameter Single Throw Shaft

TABLE B.—FORMULAE SHOWING THE ALUMINUM REDUCTION OF VARIOUS OXIDES

Metallic oxides		Aluminum		Resultant slag		Resultant metal
$3Fe_3O_4$	+	8Al	=	$4Al_2O_3$	+	9Fe
Fe_2O_3	+	2Al	=	Al_2O_3	+	2Fe
$3Mn_3O_4$	+	8Al	=	$4Al_2O_3$	+	9Mn
Cr_2O_3	+	2Al	=	Al_2O_3	+	2Cr
WO_3	+	2Al	=	Al_2O_3	+	W
$3V_2O_5$	+	10Al	=	$5Al_2O_3$	+	6V
$3TiO_2$	+	4Al	=	$2Al_2O_3$	+	3Ti
3NiO	+	2Al	=	Al_2O_3	+	3Ni
MoO_3	+	2Al	=	Al_2O_3	+	Mo
$3SiO_2$	+	4Al	=	$2Al_2O_3$	+	3Si
B_2O_3	+	2Al	=	Al_2O_3	+	2B
$3Co_2O_3$	+	8Al	=	$4Al_2O_3$	+	9Co

ductility from over 40 per cent elongation in 2 in. down to zero.

Having discussed the physical properties and the control of the analysis of Thermit steels, the next question is the degree of assurance that the operator has in making every weld sound. The extremely high temperatures so necessary for the welding operation require that the weld be poured at a temperature in

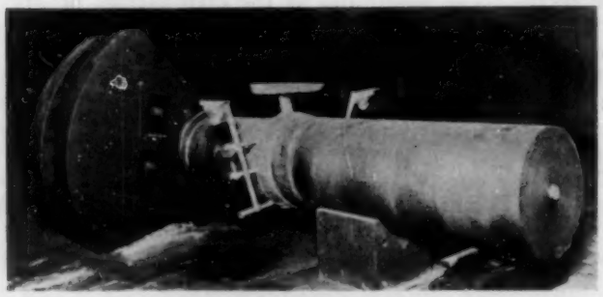


Fig. 16—A New End Welded to a 29" Diameter Shaft. In Many Cases, It Is Possible to Weld on a New Piece to Replace the Broken Part and Thus Allow Machining to Exact Size. This Is Also Typical of a Method of Replacing Worn or Damaged Ends

excess of 4000 deg. Fahr. and any one familiar with the casting of ordinary steels and the importance of the control of the casting temperature will realize the difficulties where this almost 100 per cent superheated steel is used. Fortunately, Thermit steels have one great advantage in that they are perfectly deoxidized. The steel man is a little bit suspicious of these Thermit steels because they contain a slight excess of aluminum which to him usually means trouble. The troubles that he has experienced on this account, however, may not be due to aluminum content in the steel but rather to alumina which, because of the lower temperature, may remain entrapped. In Thermit steels, the metal is as liquid as water. Great quantities of alumina are generated in the reaction and yet none of it appears in the steel itself. With such a liquid, the difference in the specific gravity of the metal and the slag (alumina) causes an almost instantaneous, complete separation.

Thermit steels, therefore, do not have to be poured at low temperatures to cause them to solidify into dense, sound castings. The presence or absence of defects in the Thermit steel depends largely upon the mold itself and the material from which it was made. The mold construction and the material from which it is made for many years was one of the stumbling blocks of Thermit welding. All kinds of high grade facings commonly found in steel foundries were used and most of the well known formulas were tried out. The fusing

Fig. 17—New 28" Diameter Neck Welded to Blooming Mill Roll

point of all clays is far below the temperature of the Thermit steel and the real difficulty was the fusion of the clay content in the mold, which was accompanied by the generation of more or less gas. The problem was finally solved by the selection of the best silica sands and clays, and the making of synthetic molding material which contains a minimum of clay so thoroughly mulled in a foundry pan that each sand grain is theoretically covered with the thinnest possible layer of plastic clay. Molding material of this kind generates much less gas when the Thermit steel is brought into contact with it but it also remains porous so that the very small amount of gas which is generated passes out through the walls of the mold and not through the steel itself. There is some danger of trapping loose grains of sand in the steel which will volatilize and form gas pockets, but by ordinary care things of this kind can be avoided so that there is really no excuse for defective Thermit welds due to molding material.

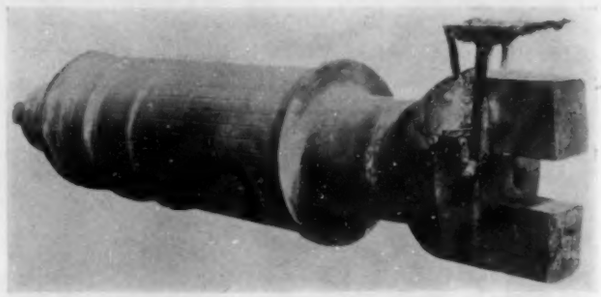


Fig. 18—Weld on End of 54" Blooming Mill Roll

Fig. 19—Weld in Heavy Cast Iron Press Head

The elimination of defects in Thermit welds was aided by a condition inherent in Thermit welding, that is, that the Thermit weld solidifies from the inside toward the outside; this, of course, tends to promote density and soundness in the weld itself. In the early days of welding before this fact was thoroughly realized, it was customary to use large risers with the idea that the shrinkage of the inner portions of the weld would have to be fed. These large risers were not only wasteful but actually harmful. It must be obvious why this shrinkage is so different from that in ordinary foundry practice; in the foundry, the heat from the molten steel passes out slowly through the mold, and solidification of the casting occurs first on the surface in contact with the mold and progresses toward the core of the casting, whereas in the welding operation the parts being welded act as enormous chills in the casting and extract the heat of the molten steel more rapidly from the center or core than from any other point.

Freezing, therefore, occurs first approximately along the axis of the parts and radiates outward from this point. The realization of this fact and the conclusion that large risers were harmful rather than helpful introduced a radical change in the design of welds, which fortunately at the same time greatly lowered the cost

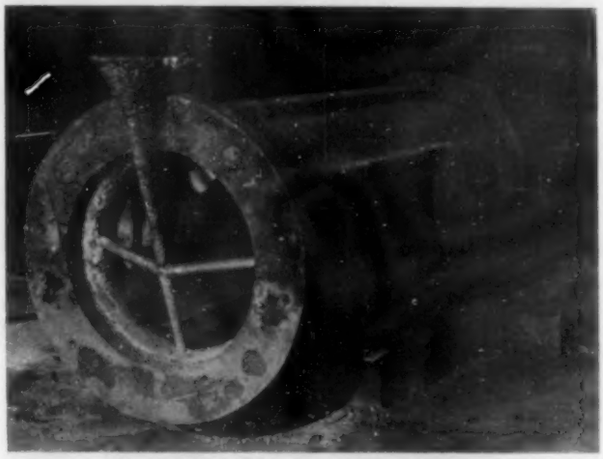


Fig. 20—Flange Welded to Cross Head Guide

Fig. 21—New Forging Welded to Shaft to Replace Broken End

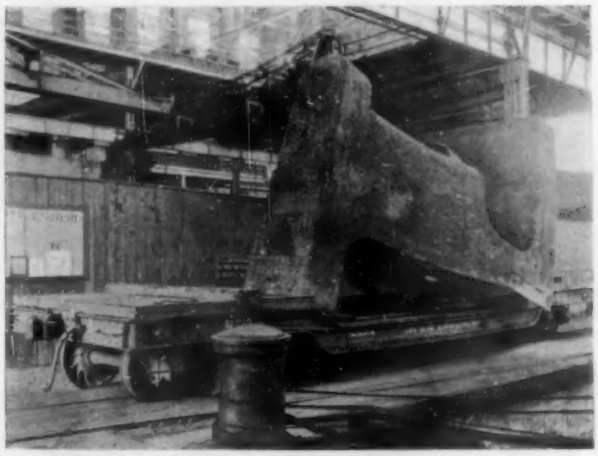


Fig. 22—Repair of Shrinkage Crack in Large Steel Casting. This Casting Formed Part of a Frame of the U. S. S. "Saratoga." The Navy Department Allowed the Welding and Did Not Insist That the Foundry Replace the Casting

of the welding operation. This decrease in cost in turn has increased the applications of welding until now it is more economical to weld almost anything in the steel mill than to substitute a new part.

In general, there are three uses for the Thermit welding process in the steel mills:

1—The repair of broken parts, which may be indicated for economical reasons or by the saving in time in getting the mill or machine into operation again.

2—The building up of worn parts, which in many cases replaces the material worn off with one better suited to withstand the service.

3—The manufacture of new constructions or the making of old ones in a new way.

All of these being important, they will be discussed separately.

Repairs by Welding

In former years, the application of Thermit welding for emergency repairs constituted almost its entire use in the steel mill. In mills where break-downs occurred

Fig. 23—Weld in 22" Diameter Roll Neck to Replace Badly Worn Wabbler End

infrequently, outside Thermit welders were called in to take care of these emergency repairs. The emergency value of this form of welding is admitted and thousands of cases could be recounted where resorting to Thermit welding has allowed the mill to resume operations in a fraction of the time which would be required to manufacture new parts. Photographs reproduced herein will give some idea of the possibilities of such emergency repairs. The important thing, however, is for a steel mill to have a proper Welding Department of its own where not only emergency repairs can be made but where a large number of routine repairs can also be made. As an example of the repairs which can be made, which are a day to day operation in some mills, the following list is taken from the work done in a period of a few months in one large steel mill. (Each item is mentioned only once although a number of each were welded.)

Cast steel tin mill housing.
Seven and one-half inch driving axle.
Frame of open-hearth charging machine.
Open-hearth charging peel.
Fifteen-inch diameter roll neck.
Replacement of pods twisted off pinion.
Weld through 23½ in. diameter neck of nickel steel pinion.
Side guard post of manipulator rack.
Numerous table rolls.

Fig. 24—Mill Pinion with Wabbler Ends Built Up

Twenty-eight inch diameter single-throw crankshaft for steam engine of automatic reversing blooming mill.

And in another mill in about the same period:

132 in. cast steel plate mill housing.

Teeth replaced in numerous 40 in. herringbone pinions.

Cast iron roll of structural mill.

Replacement of entire wabbler end of steel roll.

Replacement of wabbler end of spindle of slab mill.

Repair of broken locomotive frame.

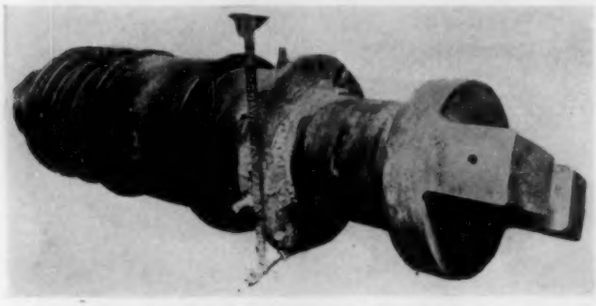


Fig. 25—Collar Replaced on 54" Blooming Mill Roll

In other mills in about this same period, we see a long array of the usual repairs of mill housings, wabbler ends of rolls and pinions, numerous crankshafts, machine frames, universal drives, gear wheel teeth, and similar parts too numerous to mention in detail. In all cases, not only was there an enormous saving in time, but the repair cost only a very small fraction of the value of a new part.

Replacement of Wear

The introduction of Welding Departments in steel mills broadened the character of the work so that it is now no longer restricted to emergency repairs. One of the newer applications is the replacement of metal worn off and this has proved exceedingly profitable. In many cases, it is possible to add in this manner a metal with wearing qualities which is a real improvement over the wearing qualities of the metal in the original piece. Rolls, pinions, spindles and many other parts must be designed for toughness and strength which preclude the use of steel having maximum wear resistance. It is perfectly feasible in the replacement of the worn pods of these parts to use a Thermit which will produce a steel of any desired hardness. It is common practice to select Thermit steels which are so hard as not to be machinable, the weld being made so true to size that no machining is required.

Fig. 26—Close-up of Built-up Wabbler End with Gates and Risers Still in Place

Fig. 27—End View of Built-up Pods. One of These (Not Yet Welded) Shows the Amount of Wear, and the Other Three a Corresponding Wear Replaced with Super-Hard Steel

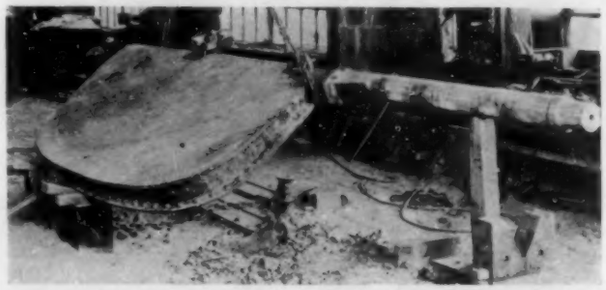


Fig. 28—Worn Rudder Stock Replaced by Welding on Completely Machined New Part

New Constructions

Welding processes have opened up a wide field and have greatly changed the methods of manufacture not only in the parts of machines used in the mill but in many of the products of the mill. New applications and changes of this kind are being brought into use daily. It is perfectly feasible for the steel mill to make wabbler ends of a steel offering the greatest possible wear resistance and to Thermit weld such wabbler ends to the necks of ordinary rolls. In the same way, new

charging peels can be kept on hand, which can be welded as required to replace broken or worn ends. Thermit steels of extreme hardness may be cast on surfaces subject to wear, or in the bore of cylinders and, in fact, any parts may by means of welding be designed to have different physical properties at various points. All of these things lead to the making of parts with greatly prolonged operating life and the corresponding elimination of the expensive replacements, shut-downs and other repairs.

The process also allows for the elimination of expensive and intricate castings and substituting therefor simple forgings which can be welded together. An interesting example of what can be done is that of a large steel company which is now manufacturing frogs for track work in which it uses a high grade steel casting for a center plate and to this, by means of Thermit steel, weld arms of rolled steel rail. In this way, a steel of excellent wearing qualities is secured for the point where impact is the greatest but the difficulties and expense of using this steel throughout the entire piece are eliminated. Many other examples could be cited but repetition is not necessary as dozens of applications

Fig. 29—Toes of Tunnel Shield Jacks Remodeled

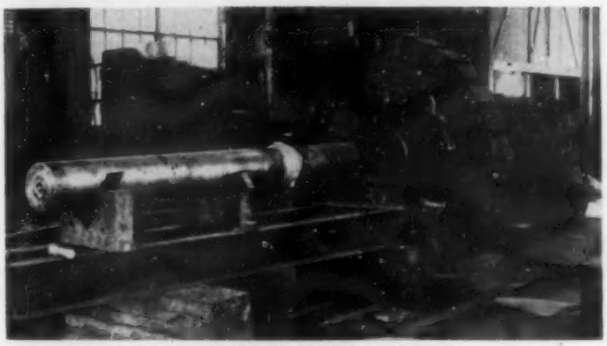


Fig. 30—Worn Rotor Shaft Replaced by Oversize Piece

Fig. 31—Press Columns Lengthened by Adding in Pieces

Fig. 32—Rotating Clinker Bars Manufactured in a Simple Way

Fig. 33—Unfinished Crankshaft Lengthened to Suit Change in Design

Fig. 34—Weld in 14,000-Ton Forging Press Cylinder

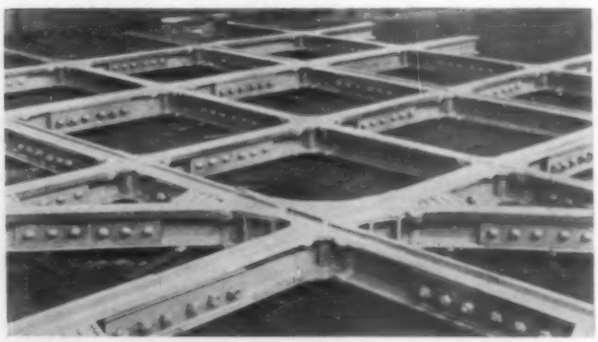


Fig. 35—Large Special Track Work Layout Composed of Hard Steel Centers Thermit Welded to Standard Open-Hearth Rails

of this kind will readily appear to any one familiar with manufacturing processes in steel mills.

The co-ordination of the various departments of steel mills in welding work is most important if fullest benefits are to be enjoyed. It is, of course, not feasible to have a number of independent welding departments in one plant, nor is it feasible for the various mill superintendents to keep in close touch with a central welding department. This question has been solved in certain mills by the organization of a reclamation department under a suitable head, who, together with the mill superintendent interested, has the final say as to which broken or worn parts should pass on to the scrap pile and which should be reclaimed. The mere existence of a welding department and experienced welders will not in itself effect the desired economies, and the installation of a co-ordinated reclamation department, or some suitable substitute, at present seems very important.

732-Mile Pipe Line Is Welded with New Process

By A. F. DAVIS

✦ Mr. Davis is vice-president of the Lincoln Electric Company.

A NEW long distance pipe line which will be used for the transportation of petroleum products from the oil fields of Oklahoma to the Gulf refineries located in Ohio and western Pennsylvania, has recently been completed. This line, which originates in Perryman, Okla., was constructed by the Gulf Pipe Line Company of Pennsylvania. It consists of a main line 732 miles long, constructed of

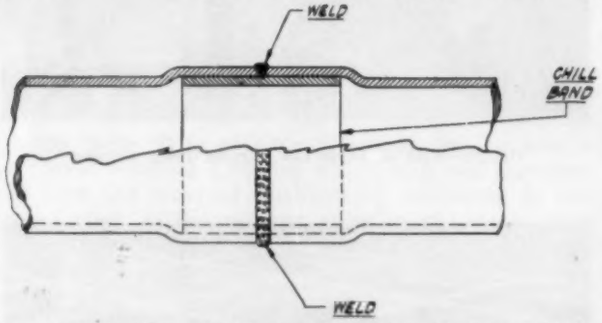


Fig. 1—The Weld Fuses the Pipe Section Together and to the Chill Band Making the Entire Line One Integral Steel Unit

Fig. 2—Showing an Operator Making a Firing Line Weld on the Gulf Pipe Line

10-in. pipe, and a branch line of 8-in. pipe, 51 miles long.

The main line of this project runs from the oil fields of Oklahoma to Spencerville, Ohio; thence to Toledo, Ohio, and Pittsburgh, Pa., by way of the old Buckeye Pipe Line Company's line. The branch line is taken from the main line at Dublin, Ind., and runs to the Gulf refineries at Cincinnati, Ohio. The work on the branch will begin some time after Jan. 1, 1931.

The construction of this new line involved practically all the latest developments in efficient pipe line construction, including arc-welded joints in the firing line. National seamless tubing and Lap-welded Standard pipe, equipped with double bell and chill band joints, were used. The pipe lengths averaged approximately 40 ft. and weighed 40 lb. per lineal foot. Each pipe length is belled at both ends and the ends are beveled so that in arc welding the joint the weld penetrates through to the chill band, as shown in Fig. 1, making an exceptionally strong and rigid joint.

Before the construction of this new line was begun the Gulf Pipe Line Company conducted a series of tests of arc-welded joints for pipe line work. As the result of these tests a new process was adopted for use on the new line which utilizes the shielded arc, a recent development of our company. Welds made by this process were found to be stronger and more ductile than those made by other methods of welding. They are also highly resistant to corrosion

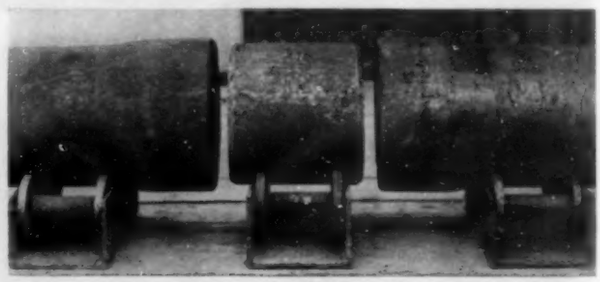


Fig. 3—Showing the Double Bell and Chill Band Joint Before Being Completed

Fig. 4—The Joint Complete Ready for Arc Welding

because they are made in an atmosphere void of oxygen and nitrogen, which when coming in contact with the weld metal while in the molten state, cause oxidation and nitration. This process also allows the welding to be carried on at a high rate of speed. In a number of cases operators completed more than 50 welds per 9-hour day. Fig. 2 shows an operator making a firing line weld.

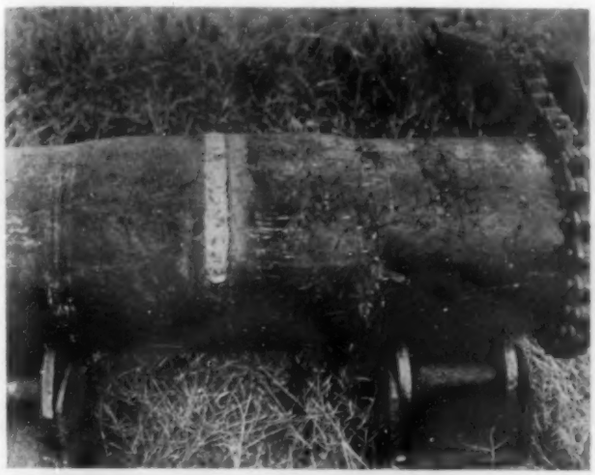


Fig. 5—The Completed Joint Just After the Finished Bead Was Completed

As sections of this pipe line were completed they were tested for tightness in preparation for turning the oil into the line. The section from Spencerville, Ohio, to Dublin, Ind., distance of about 78 miles, was tested with air at 130 lb. per square inch, and only one small pin hole was found. This hole was repaired and the pressure was kept on the line for four successive days. At the end of the four days the pressure had dropped only ½ lb. On another section of the line, Dublin, Ind., to Edgewood, a distance of about 193 miles, the line was tested to a pressure of 100 lb., and no leaks were found.

The result of these tests indicate the thoroughness and constructive ability of those in charge of the building of the Gulf Pipe Line Company's line as well as the efficiency of the welding process which they employed. Through rocky country, desert sand, hills, gorges, rivers, marshes and forests, in all varieties of weather this line was pushed to a speedy and satisfactory completion.

The method of lining up the pipe and completing the firing line welds is shown in Figs. 3, 4 and 5. Fig. 3 shows the chill band in place in one pipe length just before the joint is completely lined up for welding. In Fig. 4 the joint is completed ready for welding. In arc welding the joints on the firing line two beads are used. The first bead is made with a ¼-in. electrode. This bead is followed by the finishing bead, made with a 5/16-in. electrode. Fig. 5 shows the finishing bead in place. About 10 minutes are required to complete one of these joints.

As is customary in pipe line construction the pipe was lined up on sections for welding and the pipe turned as the weld progressed. These sections were then rolled over the ditch and welded into place on the line. The sections vary in length from 5 to 12 pipe lengths, depending on the terrain.

When completed this pipe line will be served by 14 pumping stations, each equipped with oil engine driven reciprocating pumps. The line will have a working pressure of approximately 700 lb. per square inch and a capacity of 35 to 40 thousand barrels per day.

Oxy-Acetylene Welded Experimental Metal Base Roadway

By DeW. ENDICOTT

✦ Mr. Endicott is connected with the Technical Publicity Department of the Linde Air Products Co.

OVER a year ago it was first suggested that public highways be constructed of welded steel plate. Recently the first stretch of experimental highway with metal base and curb welded has been completed in Sangamon County, Ill.

The test type of concrete roads or highways do not have the life that they were originally expected to give and the maintenance of these roads has proved extremely costly. The rigidity of materials previously employed and their inability to withstand the expansion and contraction of temperature changes and the freezing of absorbed moisture have been the causes of this costly maintenance. In promoting the idea of the welded metal base highway, it has been the aim to develop a new type of highway which will overcome past difficulties and result in a road which is smooth riding, economical to construct, and with extremely long life and low maintenance cost.

In highway construction, the chief function of any pavement is to bridge over the inequalities of the subgrade and present a smooth and even surface to traffic. While the earth itself finally supports all of the weight, every subgrade will occasionally develop inequalities or soft spots which the pavement must bridge or span. If the pavement is of rigid material, the first indication of such subgrade weakness is a crack or break in the pavement and a settlement of the entire slab necessitating expensive repairs, and consequent traffic delay. On the other hand a welded metal base covered with a flexible wearing course is a truly flexible type of payment. In the welded metal base there is sufficient rigidity to bridge or span any ordinary inequality of the subgrade and also in the event of a large or serious subgrade failure, this type of payment will show a gradual sagging or deflection which is an adequate danger signal. This sagging can then be very easily corrected by jacking up or raising the whole structure at the point of settlement and underfilling it by tamping or by means of hydraulic pumps and the pavement may be easily brought back to a true alignment. This can be accomplished with a minimum of expense and inconvenience to traffic. When the repair job has been completed the

pavement will be as good as new and will not develop cracks or breaks during such repairs procedure. A metal base will not absorb moisture and expansion is perfectly controlled by pre-designed expansion joints properly placed.

Welded metal base pavement will have many advantages over the present designs of pavement using a heavy base. In our larger cities the saving in grading effected by a welded base would amount to considerable money. Large additional benefits would accrue to merchants due to the fact that no curing period is necessary and interruption to traffic due to same will be eliminated. When service cuts are necessary the wearing surface could be removed, a section of base cut out with an oxy-acetylene blowpipe, and this same section of base welded back in place with practically 100 per cent of salvage materials. The ability of a welded metal base to bridge over a trench, should settlement of back fill take place, together with the fact that the welded plate is an integral part of the entire base, will prove interesting to city officials charged with street maintenance. Trench depressions are responsible for a large majority of rough riding streets.

The experimental stretch of highway recently completed in Illinois was divided into three sections of slightly different construction. In two of the sections the underlining plates were laid with overlapping corrugated galvanized sheet. In one of these sections the sheets were laid with the corrugations parallel to the center of the road while on the other the corrugations ran transversely. On the third section flat sheet overlapping at sides and center ends were used. The sheets of all sections were tack-welded by the oxy-acetylene process, each sheet twice on each side and one on each end. Fig. 1 shows the welder tack-welding the sheets on the sections where the corrugations ran parallel to the center of the road. The welders were able to progress much faster than were the men who were actually laying the sheet and welding proved very satisfactory as the method of joining. The success of this experimental stretch will mean the use of this method of construction in many future state highways.

Fig. 1—Corrugated Sheet Tack-Welded in Construction of Metal Base Highway

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SEND THEIR NAMES AND ADDRESSES TO THE SECRETARY OF THE SOCIETY.

X-Ray Inspection of Welds

Methods—Apparatus—Results

By HERBERT R. ISENBURGER

✦ This paper was presented at a joint meeting of the New York Sections of the American Welding Society and the American Society for Steel Treating, March 9, 1931, by Herbert R. Isenburger, Secretary-Treasurer, St. John X-Ray Service Corporation, 505 Fifth Ave., New York.

WITH the development of automatic welding equipment, welding is being more and more employed in engineering structures. In numerous cases it is desirable to have a nondestructive test which will prove the soundness of the weld and at the same time give the assurance that the material will stand the required strain of service. The X-ray is a sure and reliable means of examining the interior condition of welded joints without destroying them or in any way impairing their usefulness.

Engineers will find that X-ray inspection is the

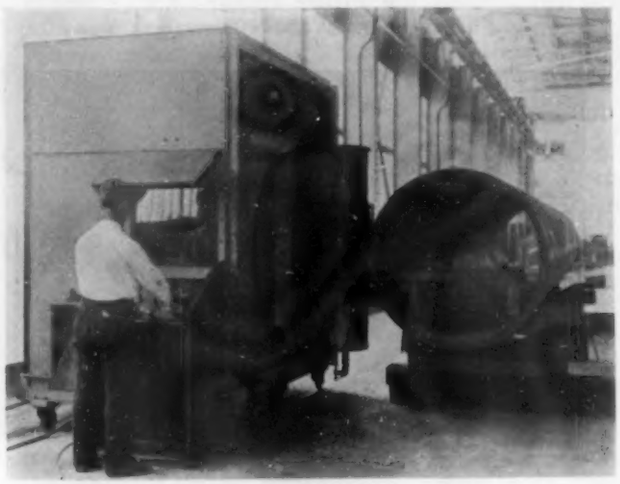


Fig. 1—X-Ray Installation in the Boiler Shop

answer to the following oft-repeated questions and the SOLUTION of these problems:

1. Is a weld sound throughout?
2. Are there any inclusions of gases, slags, sand or other imperfections like laps?
3. Is the welding rod of the proper size and was the current density appropriate?
4. How did the fusion turn out (thorough penetration)?
5. Did any cracks develop within the welded section or the neighboring region and what causes such shrinkage?
6. Has the correct speed been used for a given welding operation?
7. Was the coating of the rod satisfactory?

With the proper interpretation and utilization of the X-ray evidence, not only will the welding process be improved, but the welder's work can and will be controlled and bettered. This should not be a means of selecting good workmen from bad, other tests are provided for this purpose. But a sound weld depends

Fig. 2—X-Ray Machine in Action; Notice the 18-In. Spark Gap

upon so many things which are only too easily disregarded in routine work, especially where men are working against time. With Exographs available the welder should be taught to use the right technique for a successful welding operation. In practice, sample welds should be made in scrap pieces of plate of the kind to be used in construction; and these should be X-rayed. Films of the preliminary welds are studied and the technique is accordingly modified. As soon as the test plates are perfect and the correct procedure determined, production is started. Also, test coupons should be X-rayed at intervals while the work is in progress.

More important structures, like welds in pressure equipment for high-pressure, high-temperature service, should be X-rayed completely. Fig. 1 depicts our installation at The Babcock & Wilcox Co. at Barberton, Ohio, an original design by Dr. Ancel St. John for routine inspection of welded pressure vessels in

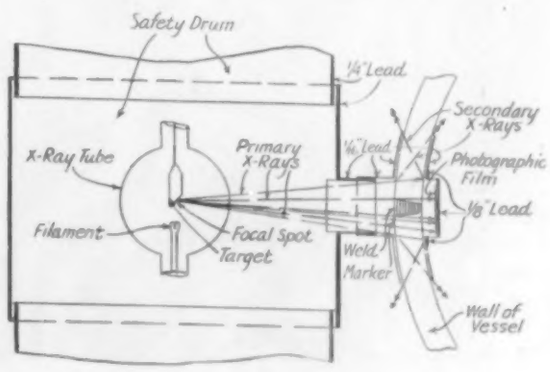


Fig. 3—Radiographic Exposure Arrangement

the boiler shop. A boiler drum is set up for inspection of the longitudinal weld. The high tension power plant is mounted on a movable platform and surrounded by a sheet metal housing. A similar X-ray machine in action is seen in Fig. 2 which is a view from our own laboratory in Long Island City, N. Y.,

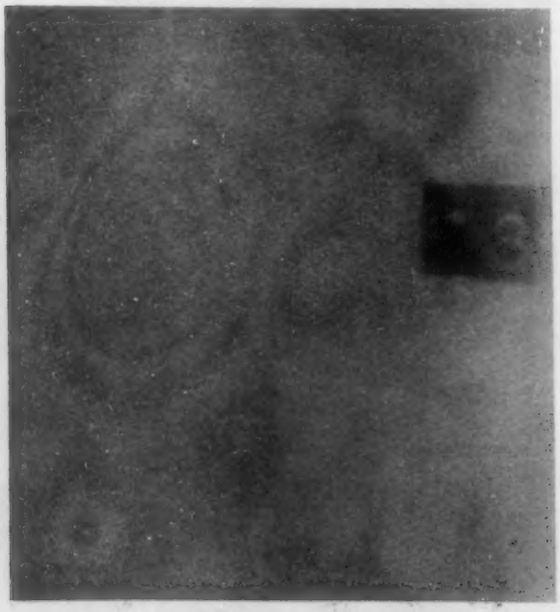


Fig. 4—Exograph of Longitudinal Seam; Sound Metal 2¼-In. Plate

with the author operating the controls. In Fig. 1 the safety drum, containing the X-ray tube, is seen in front of the housing; the tube can be rotated about its axis and raised and lowered when desired. The control cabinet is also attached to the housing. For examination of girth seams, the vessel can be rotated about its axis. A diagram of the exposure arrangement is reproduced in Fig. 3.

A typical Exograph of a longitudinal seam is shown in Fig. 4, 2¼-in. plate. The weld itself is not distinguishable because the weld metal is perfectly sound. The weld

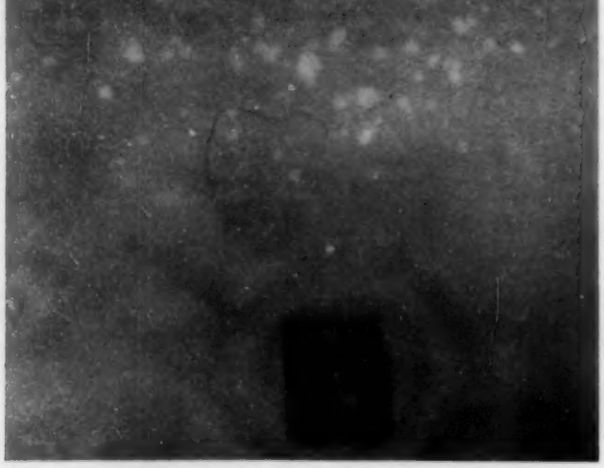


Fig. 5—Exograph of Porous Weld in 2¼-In. Plate

zone can only be differentiated from the plate and located by its relationship to the images of the reference markers which were placed on the drum at a definite distance from the center of the welded joint. Such perfectly sound welds can and are frequently being made; no manufacturer has to fear to prove this to his customers, who otherwise feel suspicious. Gas holes, whether large or small, appear as sharply defined rounded spots as in Fig. 5. The welded zone in this case can be readily located. In Fig. 6 slag inclusions extending along the walls of the joint are indicated as more or less cloudy elongated areas.

For certain materials X-ray inspection may tend to be a rigid test, calling for skill in the interpretation of the Exographs combined with thorough knowledge of the material's ultimate use. Its results, therefore, have to be studied carefully and whenever possible, expert advice should be obtained.

Figs. 7*a* and *b* show electric arc welded test plates ⅝ in. stock made by the same welder. The material is an alloy steel, the weld is V shaped, and welded from one side, as used in welding small tubings. Exograph *a* depicts conditions in the weld as originally submitted for examination. Besides showing the distribution of the weld metal, there are numerous white spots plainly visible within the welded region; some of them seem to lie in one line. These indicate bad fusion on the bottom of the V. Spots indicated by arrows are gas holes along side the scarf. After having studied the X-ray picture, the welder changed his procedure accordingly in the manner above described, and after he

Fig. 6—Exograph of Weld in 2¼-In. Plate Containing Slag Inclusions

had made four test plates, he was able to turn out a weld as reproduced in Fig. 6*b*. He then started production welding of a number of alloy steel tubings; all welds in these tubings were X-rayed. The exposure technique is illustrated in diagram Fig. 8. The weld is covered by three exposures made on the same film, as shown in Fig. 9. Such tubings are widely used in superheaters, oil crackeries, and various other severe services. On larger tubings and welded pipes the films are placed inside behind the welded seams. Welded pipe lines can be examined in the field. The X-ray equipment is mounted on a truck with the X-ray tube extending over the pipe.

All welds shown so far were made with the electric arc. It is equally important to inspect gas welds. Fig. 10 shows an acetylene weld which is rather good. Notice the built-up metal over the bottom of the V in contrast to Fig. 7.

With the use of welded building structures, the need for a thorough inspection arises; here, X-rays will be

of important value. Critical joints which are made in the shop can be X-rayed before leaving the factory. But welds made while the structure is being erected have to be inspected on the job. X-rays have been employed in routine inspection of welded beams in Germany, where an all-welded railroad bridge was tested by means of visual inspection in the field. This is illustrated in Fig. 11. The electrical equipment, dark room and living quarters for the operating crew are placed inside the railroad car. The X-ray tube is set up for visual inspection. Whenever a suspicious place in the weld is discovered, an Exograph is made at that point to verify the visual observation.

It may be well to add a few words about fluoroscopic inspection, since in quite some cases it is desirable to look through the metal rather than take pictures. This can be done with fairly reasonable possibilities if the material is not thicker than ½ in. Radiographic examination with photographic film should, however, be preferred, since this is the more sensitive way; visual inspection in a fluorescent screen is the faster and cheaper one. The film leaves a permanent record, whereas the screen does not give a record; in the latter method one not only relies on the momentary judgment of the operator, but also many defects cannot be observed on the screen, which would show up on a film. The appearance of the various defects can be raised up to 1 per cent precision in radiographic examination of ½ in. of steel, but to not better than 4 per cent in visual inspection of the same thickness. Furthermore, special precautions have to be taken for the arrangement of the fluoroscopic observation stand, since otherwise the operator is exposed to the dangerous X-rays. Our specially designed and recommended arrangement is schematically shown in Fig. 12.

A very important field for X-ray inspection of welds lies in the aircraft industry. Various fuselage joints of an airplane structure are seen in Fig. 13, the largest group of which comprises five pieces of chrome-molybdenum steel tubing and two reinforcing plates. The details of all joints in this assembly show up nicely, including a region near one joint where the tubing was unduly thin just adjacent to the edge of the weld metal and unduly thick slightly further away. In some parts fine porosity and cracks are observable in the negative, but unfortunately these details are lost in reproduction.

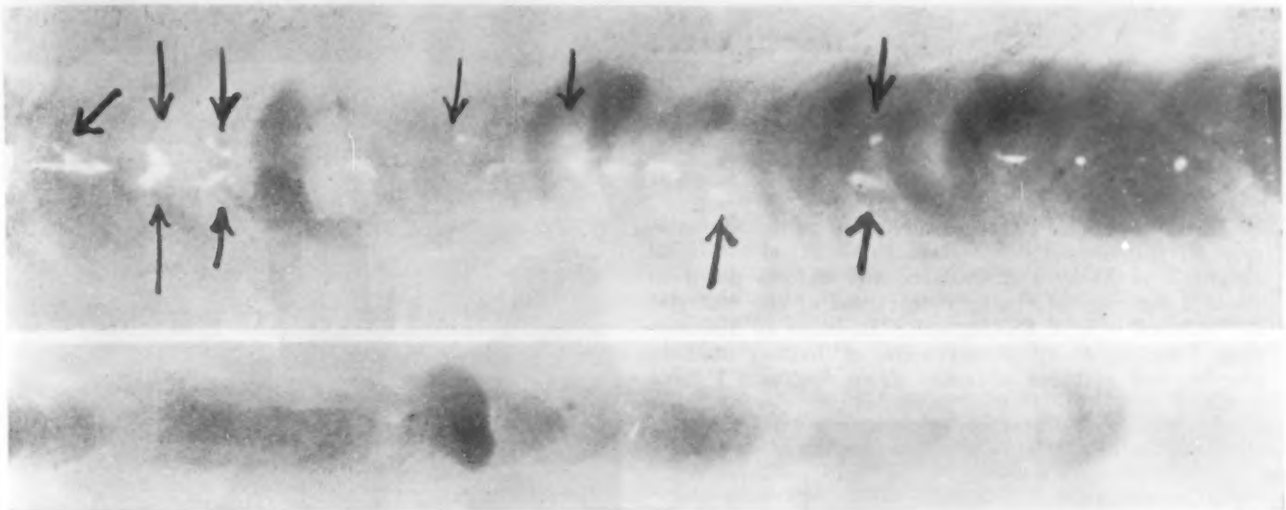


Fig. 7a—(Top) Electric V Weld in ⅝-In. Steel Plate, Showing Cavities. Fig. 7b—(Bottom) Same Weld After Studying the X-Ray Evidence

Welding is frequently employed in repair shops. Figs. 14*a* and *b* are prints made from one and the same negative, illustrating a weld in cast steel. The casting had a thinner cross-section than the weld metal, and therefore appeared somewhat overexposed in the film. In *a* we have the details through the steel casting, and in *b* the Exograph of the weld. Altogether, it is a bad weld in a worse casting. In general, it is not advisable to repair cast steel by welding.

In steel ranging from 1 in. to 3½ in. in thickness, defects down to 1 per cent of the total thickness of the material under investigation are observable in the X-ray picture; in steel less than 1 in. thick even finer defects can be detected. It does not take longer to examine one foot of weld than 1 minute through 1½ in. of steel, whereas 3 minutes are required to penetrate

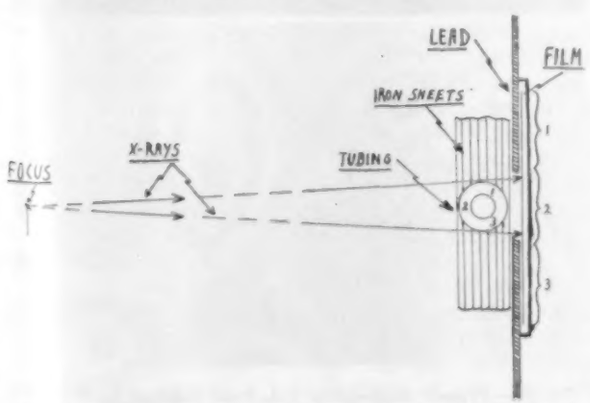


Fig. 8—Diagram of Exposure Technique for Small Tubing Inspection

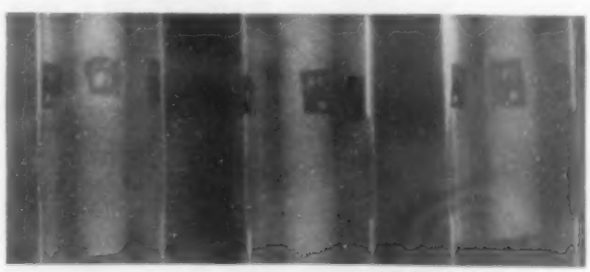


Fig. 9—Exograph of Weld in Small Tubing

through 2¼ in., and 20 minutes for 3⅛ in. of steel. In order to keep within economical exposure limits, it is not advisable to examine thicker materials by means of X-rays, although 4 in. and even 5 in. of steel have been successfully Exographed. We are using Gamma-rays from Radium on thicknesses above 3½ in. and up to 10 in. of steel. It is not advisable to use Gamma-rays on thinner materials since this method is not as sensitive as X-ray examination, and defects down to about 3 per cent of the total thickness of the material are observable in a Radiograph. In order to differentiate between X-ray photographs, or better, shadowgraphs, and pictures obtained from Radium, I have called the first ones Exographs the others Radiographs.

X-ray inspection of various welded structures in place has been successfully employed in Germany, for the examination of locomotive fire boxes, boiler drums, ships and railroad bridges; in England, for the examination of aircraft materials; and in this country, for the in-

Fig. 10—Gas V Weld in ⅝-In. Steel Plate, Rather Sound

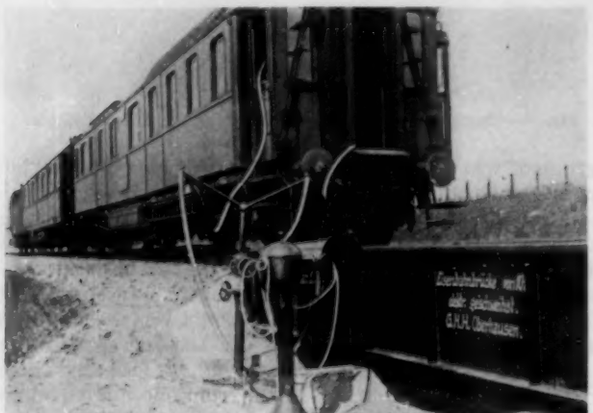


Fig. 11—Visual Inspection of Welded Structure in the Field. (Courtesy Richard Seifert & Co., Hamburg, Germany)

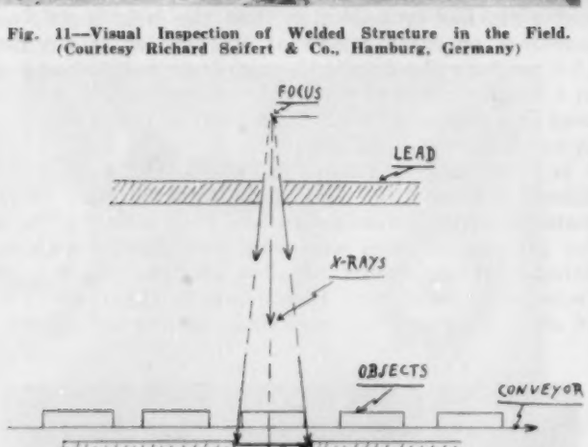


Fig. 12—Fluoroscopic X-Ray Inspection Method

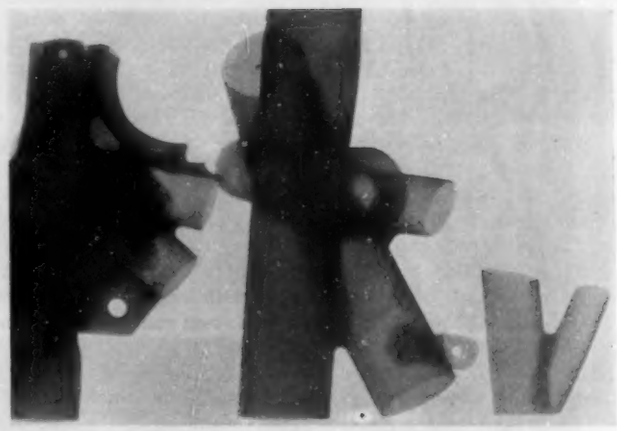


Fig. 13—Welded Assemblies of Airplane Fuselage Members

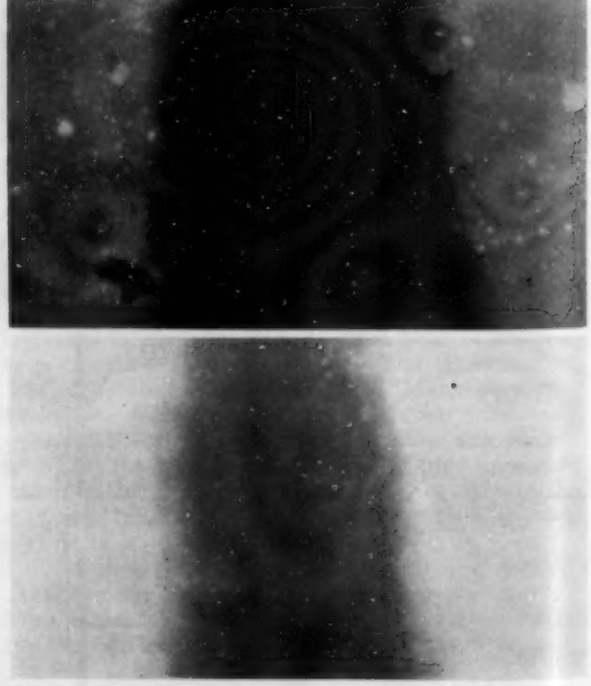


Fig. 14a—(Upper) Exograph of Cast Steel Repaired by Welding; Details Through the Casting. Fig. 14b—(Lower) Same, Details Through the Weld Metal

spection of ordnance structures and pressure vessels.

The cost for suitable X-ray installations and their operating expense depend a great deal on the material to be examined, its thickness, conditions and mobility. A conservative estimate of operating cost is $3 to $5 per hour, depending on the way the equipment is written off. X-ray equipment, however, should not be installed until the adaptability of the method to the problems in hand has been demonstrated, and not then unless the benefits to be derived justify the investment. This would seem to make the tool unavailable to the organization with a small problem or a temporary difficulty. But fortunately some of the pioneers have installed X-ray equipment and are prepared to take care of such cases, so that it is possible to evaluate any proposed use of radiography without great expense. On the other hand, an X-ray installation can and does pay for itself within the first year.

Modern developments in electric arc welding and the experience in welding practice will eventually convince the purchasers and operators that structures and pressure systems, welded under correct procedure control and proved by the X-ray to be perfect, are eminently safe and desirable. At present, it is as unfair and intemperate to say that all welds are bad as it is to say that all welds are good. Means are available for separating the good from the bad, and any user of metal fabrications, who fails to use them, is blinding himself to opportunities which are being grasped by his competitors.

Welding in the Heating and Piping Industry

By **JOHN H. ZINK**

✦ This paper was presented at the Annual Meeting of the A. W. S., April, 1931, by John H. Zink, president, The Heat & Power Corporation, Baltimore.

IT has been my good fortune to be associated with much of the direction of welding activities in the piping field during the past few years, and this experience has given me first-hand knowledge of the splendid and generous contribution your members have made for our mutual benefit in research and development work. I am happy to make this statement because it gives credit where credit is due. That our joint leadership of sales promotion has not kept pace with these excellent results is both unfortunate and too much in evidence, and it seems to me we must now give constructive consideration to this important branch of activity if welding is to maintain its position of power and prestige. It is my opinion that the abuses directly attributed to ignorance will be finally corrected, so that we are primarily concerned with the misrepresentation to which welding is being subjected by sales promotion policies too much influenced by the dollar rather than conscientious merchandising. Since the finger of responsibility pertaining to these unethical practices may be pointed at some of our contractors as well as to some of those who sell welding equipment, it will be consistent for me to briefly review both sides of the question to justify my plea for more determined administrative control by our respective Associations. As I see it, the purposes of The American Welding Society and our National Association are identical with respect to welding promotion and protection, and a unified plan of promotional control will do much to overcome individual practices predicated on "every man for himself."

Welding was introduced to our Industry as a suggested method of installation at a time when neither the contractor nor our pipe fitting manufacturers were prepared to satisfactorily adopt its use. Nevertheless, through the generous co-operation of our respective members, welding is now ready to be certified as the preferential method of pipe installation. The possible exception is small residence heating plants, but contemplated piping material improvements made possible by welding will eventually make this exception unnecessary.

Nothing has been offered to our Industry during my experience that presented the same opportunity for diversified and economical use in intelligent hands as does the welding process. It is, therefore, extremely unfortunate that welding should be burdened with some inconsistent sales policies which become an indictment against its reputation and directly affects the position of the responsible piping contractor.

If my experience means anything, it has definitely taught me that welding is an art requiring the best technique of workmanship and design, at least an elemental knowledge of heat treatment, and to know something about the metallurgy of piping materials. To these I might add financial and moral responsibility which include a willingness to contribute in some measure to Association work in order that the economic value of pipe welding may not be depreciated. Give welding a set of by-laws similar to these requirements, and we will safeguard it against indiscriminate sale and use, and prevent it being misrepresented as an answered prayer to meet a business depression.

My criticism in this respect, if such it be, is directed to the contractor who does not accept his management responsibility for quality welding similarly as he does, or should, for the other branches of his business. Our contractors may be divided into three classes with relation to their attitude toward welding.

(1) Those who merchandise welding with a background of financial and mechanical ability supported by courage, sincerity and a full sense of Industry responsibility.

These contractors represent an integral part of the building industry and as such merit your confidence and support because welding progress in our field will be best promoted under their direction, and as continuous customers for your products justify at least the same consideration as is now given to the one time user.

(2) Those contractors who believe and are taught that the simple expedient of purchasing a welding outfit automatically qualifies them as fool-proof welding experts.

Misdirection of effort, and in some instances, with good intentions, is the principal contributing cause for

originating this type of welding organization. Many of these contractors will be responsive to constructive assistance, and our National Association as well as The American Welding Society should accept their educational responsibility to them. To be effective, the program of the two organizations should be substantially the same.

(3) Those who resist welding through their own limitations and on account of tradition.

The contractors under this classification need give us no concern. For many reasons they will never catch up with their business, and our crate of eggs should not be condemned simply because it contains a few bad ones.

From the foregoing, it may be very properly assumed that I do not believe that welding will be successfully used by all our contractors, but I believe welding abuses will be minimized if we adopt a procedure, as a part of our sales promotion work, of educating and qualifying the responsible contractor instead of concentrating on the mechanic, and we should pass up the irresponsible contractor as an unsafe investment. Any set-up that concentrates knowledge in the mechanic alone is defective and does not meet the requirements of our Industry. We should bear in mind that the contractor needs constructive education in order to determine costs, supervise, promote sales, and even more important, maintain control of his business. I cannot visualize any situation quite as distressful in our business as that of a contractor being willing to conduct his welding operations solely upon the knowledge of mechanics or direction from inexperienced outsiders.

My criticism of the aggressive sales policies of some of those who sell welding equipment is made only so far as they are unethical in violating well defined business standards. I refer particularly to those policies that misrepresent welding application and costs as well as encourage owners to do their own pipe work primarily to insure the sale of a particular welding apparatus or materials.

To relieve any nervousness as to this last statement, permit me to frankly admit that I am not foolish enough to believe that we contractors should control all piping installations, welded or otherwise. Neither do I question the right of any owner to do his own work if he has the organization to do it satisfactorily, but I do say that our elimination is being over-stressed in many cases and, unless tempered through better cooperation, will create harmful and unnecessary misunderstandings.

You gentlemen exercise a considerable influence in the sale and application of welded piping, and this opportunity carries with it the obligation of careful consideration to the basic rights of our Industry. We know that a representative pipe installation imposes more qualifications than simply making welded joints, and I question the ability of the owner in many cases to measure up to these additional qualifications, similarly as does the responsible piping contractor.

The usual argument is that the owner can buy cheap labor and save the contractor's profit. Aside from the fact that he gets exactly what he pays for in the way of quality, the difference in labor rates will be more than offset by excess man hours and other excess costs due to inexperience as to make the ultimate cost to the owner higher than that of the contractor including contractor's profit—if by pluck or luck there is any profit. Most of us are afraid to take a profit in these times because it is looked upon as a criminal offense to do so. Nevertheless, I have first-hand knowledge of some owners' costs, which, had they been given to my company as a contract would have reflected a net profit that would have enabled us to weather the present depression in a very satisfied manner—with a few dollars left over to purchase unemployment apples.

In the final analysis, I do not fear the owner as a competitor on the basis of cost and quality, and he will cease to be a serious industry problem if overstatements and misrepresentations are scrupulously avoided. The loss of this work not only affects us contractors, but to some extent affects organized labor and our consulting engineers, and they are both very much concerned.

The proper classification of the welding mechanic by organized labor is another phase of promotional work requiring constructive cooperation. It presents complex problems of rates, labor distribution, training, etc., to be settled in each jurisdiction, and we contractors as interested parties directly affected will be responsible in having this classification made to be mutually beneficial. Aside from any individual opinion we may have on this question, it is nevertheless a fact that a very large percentage of our work is installed with union labor, and we must give due consideration to this fact. By cooperative effort in the Baltimore jurisdiction, welders do not receive a separate classification as workmen. Our steamfitting mechanics are required to weld similarly as they are required to use a stillson wrench. Thus welding does not add to our labor cost, but instead, we are enabled to use it competitively in all branches of our work.

The exercise of some drastic control to insure the sale and use of specification welding rod is every day becoming more necessary. There are too many unbranded rods of undetermined specification on the market with nothing to compliment them except low price. Most of them are in the hands of jobbers who accept no responsibility beyond that of an order-taker. The seriousness of this situation is more apparent as we are considering the welding specifications for high pressure piping. It would be very gratifying to me if some method of certification could be developed whereby the user would be assured of quality in welding rods, and our Industry could well afford to pay the expense of this certification as a guarantee against using fence wire.

Dr. H. L. Whittemore, who most of you know, recently wrote a strong appeal for inspection of welding in one of our trade papers. I should like to express my approval to this appeal and add that if we don't accept our management control of welding application we may expect welding to be burdened with the additional cost of independent and compulsory inspection.

It may have been presumptuous to express my views on these trade practices at this meeting, but their importance is obvious, and giving them frank publicity is perhaps a desirable method of obtaining fair play for welding.

Description of All-Welded Auxiliary Vessel Being Built at the United States Navy Yard, Mare Island, California

By LIEUTENANT H. A. SCHADE

✦(Construction Corps) U. S. Navy, Assistant Shipbuilding Superintendent, Navy Yard, Mare Island.

THE United States Navy Yard, Mare Island, Cal., is at present engaged on the construction of an auxiliary vessel which should be of considerable interest to the welding profession. The vessel is a self propeller garbage lighter, of ship-shape form, provided with hoppers, to be used for the disposal of garbage from the fleet in the San Pedro, Cal., area, and is of all-welded construction. The keel was laid on Feb. 9, 1931, and it is expected the vessel will be completed during the summer of 1931. The ship has a length of 118 feet, 26 foot beam, with a light displacement of 159 tons, estimated.

The system of framing is longitudinal, with deep transverses, somewhat similar to the Isherwood system employed in riveted ships. The longitudinal framing is, in general, made up of 3 in. x 5 in. or 3 in. x 6 in. angles, with the 5 in. or 6 in. flange fillet-welded on edge to the shell plate. The 5 in. flange is continuous through bulkheads and transverses, while the 3 in. flange is coped out at these intersections. The shell and bulkhead plating is generally ¼ in. thick, except in certain locations where greater strength is required.

Manual arc-welding, with bare electrodes, is being employed throughout for all joints. The vessel is being built on a level keel, which considerably facilitates erection, and will be launched sideways into the adjacent graving dock. As much fabrication as possible is being carried on in the structural shop; for example, bulkheads and transverses are being completely welded up in the shop, and then transported to the ways for erection. This procedure permits the maximum use of welding in the flat position, with a corresponding reduction in the amount of side and overhead welding required.

Prior to beginning any actual work, considerable attention was given to the question of the type of joint to be used for plate seams, i.e., shell plating and decks. The original plan involved single-V butt joints for these seams, with a channel longitudinal on the seam, the faying flange of which was to be used as a strap for the butt weld. It was, however, later decided to use a

Fig. 2—Laying the Keel

joggled lap joint, double fillet welded, with an angle longitudinal T-welded on the lap. The lap joint has a number of advantages for plate seams in ship construction, viz:

(a) Lap joints eliminate the planing or chipping of plate edges to the angle required for butt joints.

(b) Lap joints are easier to assemble, involving the simultaneous joining together by welding of only two parts, i. e., the two plates involved, instead of three, i. e., two plates and the straps.

(c) Lap joints allow adjustments to be made during fabrication to compensate for shrinkage, etc., as the work progresses, since the width of the lap need not be held to a rigid dimension, whereas plates for butt joints, once cut and planed to size, must be welded together in fixed relation to each other.

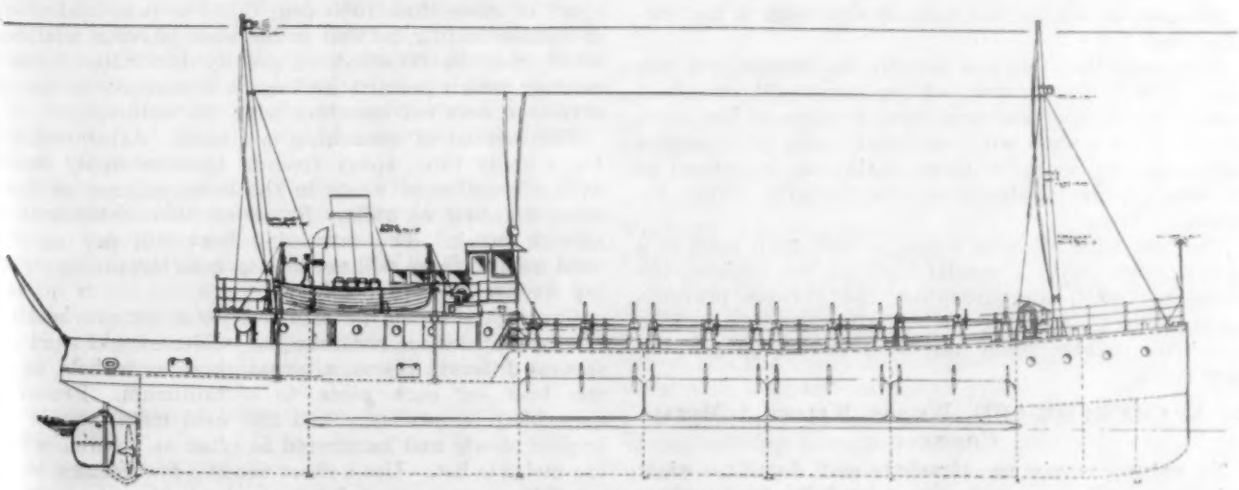


Fig. 1—Outboard Profile

(d) The lap joint results in considerably less transverse shrinkage than the strapped butt joint.

(e) Fillet welds are easier to make than butt welds, particularly in the overhead position, and hence are likely to be of higher quality.

An initial decision was made that no assembly bolts involving the punching of holes for assembly purposes only, would be used on this vessel. The parts to be welded together are placed in their proper relation to each other, which sometimes involves the use of shores, prys, bolts with heads temporarily tacked on the plate or shape, etc., where parts must be forced together; small tack welds are then applied to hold the parts in position until the finish weld is applied. This procedure is largely experimental, since the general practice heretofore has been to use punched holes and assembly bolts; their elimination cuts out the punching operation, and the welding up of the assembly bolt holes after welding. Instead of laying out bolt holes, pitch marks are laid out on the parts to be assembled, and the distance between pitch marks held to a certain dimension when the parts are brought together.

Wherever neither watertightness nor extreme strength is a requirement, intermittent welding will be used for T-joints. The length of the increments of such intermittent welding has been standardized at 2 in., the spacing between increments being varied to suit different strength requirements. Chain welding for these intermittent welds is used in preference to staggered welding, the intermittent welds being applied to both sides of the joint. Chain welding has the advantage of giving an increased unwelded space between increments; it is these unwelded spaces which give intermittent welding its advantage over continuous welding in the reduction of warping, shrinkage, and internal stresses, since, in intermittent welding, the shrinkage is taken up by the unwelded metal in the spaces, instead of being cumulative to the end of the joint. Chain welding has the additional advantage over staggered welding in that the heat incident to application of the second increment exerts an annealing effect on the increment directly opposite.

In view of the experimental nature of this construction, a careful record is being kept of shrinkage and deformation due to welding, both on individual joints and on the structure as a whole. Warping of plates and shrinkage due to welding, with the resulting development of internal stresses in the completed structure, have been considered major obstacles in all-welded ship construction. It is hoped that the information gained by keeping an accurate record of shrinkage data will be of benefit in future construction of this kind.

Fig. 1 shows the outboard profile, indicating in a general way the type of the vessel. The photograph (Fig. 2) shows the ceremony of "laying the keel," which consisted in joining together on the ways two sections of the flat and vertical keels which had been fabricated in the shop.

Increments on the two sides of the standing part of the T are placed directly opposite each other.

QUESTION AND ANSWER COLUMN

Arc Welding of Manganese Steel

INQUIRY

Will you kindly furnish me information as to the Arc Welding of Manganese Steel?

ANSWERS

By **C. J. HOLSLAG**, Chief Engineer, Electric Arc Cutting and Welding Company

Manganese welding with manganese rods is not satisfactory.

It is true that you can deposit manganese, but you can't give it the proper heating treatment except if welded before the heat treatment is made at the foundry, or if in a shop with annealing oven, or if welded section as well as the adjacent metal can be refined to its original grain structure and properly stress relieved.

The best wire we have found to weld such work is a nickel chrome with a special high carbon content, the nickel makes it air-hardening, the chrome prevents surface cracks, and the carbon gives a refined grain structure. Stress relief can be produced by peening each layer.

By **A. CHURCHWARD**, Wilson Welder & Metals Company

To secure maximum strength and ductility when welding manganese steel, use a rod having a manganese content of 11 per cent to 14 per cent and a carbon content of 1 per cent to 1.30 per cent. A rod of less than 10 per cent manganese will give a hard and brittle weld. The rod should be coated.

Use reverse polarity and a short arc with direct current welding machines.. By making the work negative and the electrode positive, a steadier arc is secured and there is less loss of manganese and carbon.

Thoroughly clean all surfaces to be welded, and remove all foreign matter. Vigorous brushing and cleaning is necessary to assure clean surfaces and the removal of all loose pieces.

Make a wide bead, not a narrow bead as on ordinary steel. A broad bead will keep the deposited metal in a molten condition for a longer time than a narrow bead will, and the result is less porosity.

There is one essential feature that must not be overlooked. The weld should be quenched from a temperature of more than 1000 deg. C. The beneficial effect of sudden cooling, as well as the good physical qualities which may be obtained, is greatly facilitated by arc welding which permits cooling as frequently as necessary, and does not interfere with the welding.

The method of quenching is simple. After welding for a short time, spray from a hose, or apply water with a handful of waste in the same manner as done when building up rails. Brush off thoroughly with a scratch brush. The remaining heat will dry up the weld so that there will not be any interference in striking the arc.

Great care should be exercised to avoid overheating the casting and, if possible, the welder should work on several different pieces, alternating so as to hold down the heat on each piece to a minimum. Frequent quenching is necessary and the weld metal should be applied slowly and hammered as often as possible while the metal is hot. Use a short arc and low voltage when possible to assist in holding the heat down to a mini-

mum. The practice of welding slowly, quenching the metal, hammering while hot and grinding as soon as practical are rules which should be observed at all times.

For 1/4" diameter wire, use 175 to 200 amperes
For 5/32" diameter wire, use 125 to 150 amperes
For 3/16" diameter wire, use 150 to 175 amperes

I would refer your inquirer to a report on this subject appearing in the Engineering Manual of the American Electric Railway Engineering Association, which is reproduced below.

WELDING CUPPED RAIL ENDS

1. Rod Specifications: Use only high carbon rods which comply with the specification of the A.E.R.E.A. for that type of rod.*

2. Preparation for Welding: Weld on solid metal only. Be sure the rail is not cracked under the head, as heat applied in surface welding may result later in a section of the head breaking away from the web. Tests for cracks under the head of the rail can be made by tapping the head of the rail with a light hammer. Be sure that the joint is mechanically tight. Thoroughly clean the surface to be welded of all rust or grease. Use a straight edge to determine the length of the cup and then mark these limits with chalk.

3. Welding Operations: Fig. 1 shows the correct method of applying metal to cupped rails. Start the weld on the back of the rail head and run the bead the length of the cup, then across the rail at an angle of 45 deg., then along the gage side of head to a point which will enable you to recross the head of the rail at the same angle to the starting point. Continue to weld on the inside of the area already formed, following the outline as started by the original bead until the center of the cup is reached. This procedure will avoid nicking the rail with the arc, which causes many failures. Keep the surface clear of oxides and all foreign matter at all times. Brush the weld frequently with a steel wire brush. Lay the beads close together, cutting into the previous bead about one-third of its width to assure a smooth, solid weld. Hammering the weld metal while hot will assist in removing the scale and relieve the weld of stresses. Where deep cups or broken rails are repaired, soft steel may be used at first and then covered with a heavy layer of high carbon steel to insure good wearing qualities. Satisfactory welds can be made by using high carbon steel for the full depth of the cup. Use a steady and continuous short arc with well regulated amperage to assure proper penetration. In finishing the weld, the final layer of deposited metal should be sufficiently high above the rail head so that after grinding the finished surface shows good, clean, solid metal. Hairline cracks or burnt metal indicate poor results and steps should be taken to immediately remove the causes.

4. Welding Cupped Rail Ends: Where the rail ends are separated sufficiently at the joint to allow for arc welding, the opening should be welded for the entire width and depth of the rail head so as to bring the weld up to the surface of the head, before starting to weld the cupped surface.

5. Grinding: As soon as practicable after completion of the welding operation, use a rotary grinder to remove the heavy portion of surplus metal and finish with a reciprocating type of grinder. Check with a straight edge to be sure that the cup is entirely removed and a true surface obtained.

*Chemical Composition "High Carbon Welding Electrode."

Carbon	0.95 to 1.10
Manganese	0.45 to 0.65
Phosphorus, not more than	0.03
Sulphur, not more than	0.03
Silicon	0.20

WELDING MANGANESE STEEL

1. Welding Operations: Great care should be exercised to avoid over-heating the casting and, if possible, the welder should work on several different pieces, alternating so as to hold down the heat on each piece to a minimum. Frequent quenching is necessary and the weld metal should be applied slowly and hammered as often as possible while the metal is hot. The floors and risers should always be built up first to assure the correct wheel bearing condition on the surface. Use a short arc and low voltage when possible to assist in holding the heat down to a minimum. The practice of welding slowly, quenching the metal, hammering while hot and grinding as soon as practicable are rules which should be observed at all times.

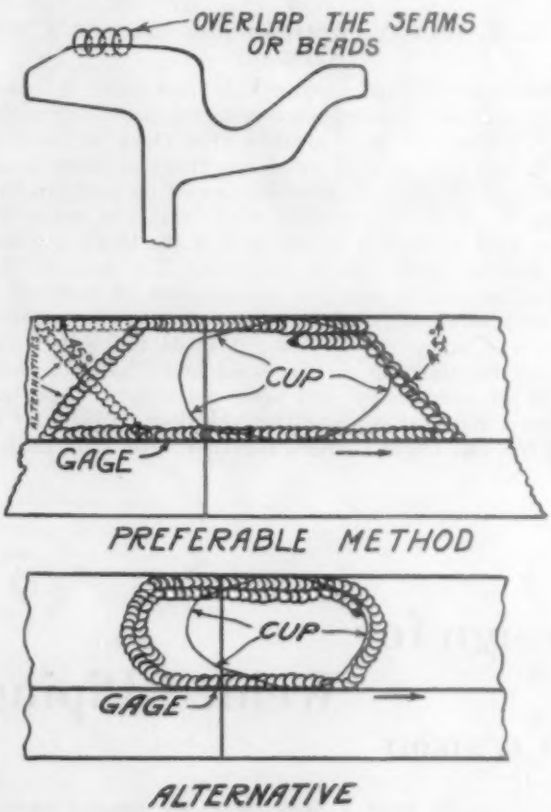


Fig. 1—Correct Method of Applying Weld Metal to Cupped Rails

2. Preparation for Welding: Thoroughly clean all surfaces to be welded, and remove all foreign matter. Vigorous brushing and cleaning is necessary to assure clean surfaces and the removal of all loose pieces.

3. Rod Specifications: Use manganese rods with a manganese content of 11 per cent to 15 per cent or high carbon rods conforming to the specifications of the A.E.R.E.A., and apply the rods strictly in accordance with instructions herein given.

4. Grinding: As soon as practicable after completion of the welding operation the weld should be ground to a true surface. It is preferable to finish with a reciprocating type of grinder. Check with a straight edge.

By **O. A. TILTON,**

In regard to the welding of manganese frogs, we wish to state that the preparation of the metal for the weld is the same as with ordinary steel, namely, to make sure that the joint is properly veed and thoroughly cleaned. There are only two other points of procedure that we can suggest for consideration in welding broken manganese frogs. The first is that care should be taken to obtain a welding wire having approximately the same manganese content as the frogs themselves, and second is that care should be taken to quench the weld metal when it is still a cherry red. Unless this is done, the resultant weld metal will be brittle, but if it is quenched at the proper time the result will be a very ductile weld and one with a higher tensile strength than is obtained in ordinary welding processes. Reversed polarity should be used.

By **A. M. CANDY, Westinghouse Electric & Mfg. Company**

One large railroad company has been doing a considerable amount of this work during the past four or five years. When it first started this class of work a large tank was built in which the frogs or other pieces of special track work could be located on suitable supports, the tank to be filled with water to bring the water level up almost to the level of the location where the welding work was to be done. The idea of this was to be sure to keep the temperature of the frog at as low a value as possible during the time the welding work was being done. Also, it made the water convenient for dashing on the weld metal after a short length of weld metal had been deposited. Later experience, however, showed that the thermal capacity of such frogs and special work, together with their radiating surface, was sufficient to take care of keeping the temperature down to the necessary value to obtain quenching of the weld metal. For this reason, therefore, the tank was abandoned. However, in carrying on the work at present, the operator has a vessel of water available so that after each run of weld metal varying from 1 to 3 in. long is placed on the manganese steel, the weld can be quenched by throwing water on it until it stops boiling the water which is placed on the weld. As soon as the water ceases to boil on the deposit and surrounding surface, an air jet is turned on to the surface of the metal so as to dry up the water quickly, and immediately after it is dry the deposited metal is peaned thoroughly with an air hammer. After the peaning operation the entire area around the deposited metal and the deposited metal itself is brushed vigorously with a wire brush to remove all scale and foreign matter. This sequence is repeated until sufficient weld metal has been deposited on the particular location to fulfill the necessary requirements.

The length of weld metal which is deposited in the form of a bead at any one time depends upon the thickness of the particular casting on which the metal is being deposited. The whole idea, of course, being to deposit only a certain amount of metal at any one point so that the surface of the work being done will not be raised to a temperature such that it cannot be readily quenched. The whole theory of manganese welding, of course, depends upon being able to quench the deposited metal quickly in order to retain the tough characteristics of manganese steel.

Special coated electrodes are required for this work which can be obtained from several different manufacturers. Also reversed polarity.

Design for Welded Piping

By **A. G. WIKOFF**

✦ Mr. Wikoff is connected with the Technical Publicity Department of the Linde Air Products Company.

IT has been repeatedly emphasized that in order to obtain the maximum benefits of welded construction, the engineers responsible for the design of the product must be familiar with the advantages and possibilities of welding and must have at their disposal data which will enable them to apply welding most efficiently to the particular product under consideration. The rapidly increasing use of welding for the construction of pipe lines and piping systems for all types of service has brought about a demand for specific information that will enable engineers, architects and others to design and specify welded pipe lines and piping systems in accordance with the best practice.

As a result of their long experience with welded construction, engineers of The Linde Air Products Company have developed standard designs for the various types of joints recommended for welded piping systems. This article summarizes the design recommendations for welded line joints in steel and wrought iron pipe. These recommendations are fast becoming the standard designs for the welding of both overland and industrial piping.

Open Single Vee Butt Weld

The open single vee butt weld, Fig. 1, is the type of weld most extensively used for steel and wrought iron pipe and is the standard welded line joint. It is easy to make, of low cost, and comprehensive tests on full-size specimens of all sizes of pipe commonly welded have shown it to be the strongest.

The open single vee butt weld is the standard line joint; it is recommended for standard, extra heavy and double extra heavy steel or wrought iron pipe for all pressures and services.

Pipe to be joined by this weld is supplied by the manufacturer with ends machine-beveled as shown in Fig. 2. The bevel does not extend to the inner wall of the pipe, a flat portion about 1/16-in. wide is left to facilitate lining up and weld depth penetration. This also serves to strengthen the edge during transit and handling before welding.

When pipe is lined up for welding, a space, S, Fig. 2 should be left between pipe ends to allow them to draw together as the cooling weld metal contracts, thus eliminating the possibility of overlapping edges or residual stresses. No allowance need be made for this spacing in design layout of piping system, as the overall length will be true within reasonable con-

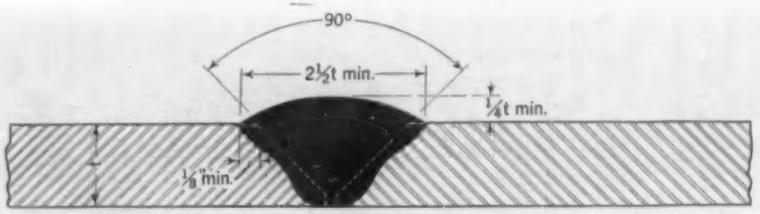


Fig. 1—Open Single-Vee Butt Weld

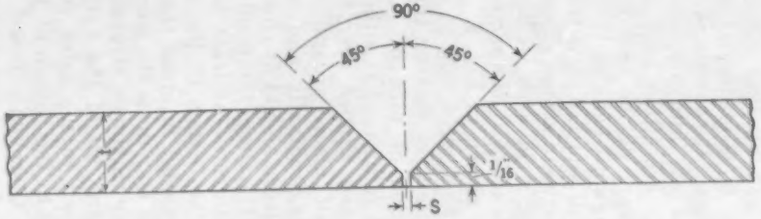


Fig. 2—Specification for Beveling Pipe

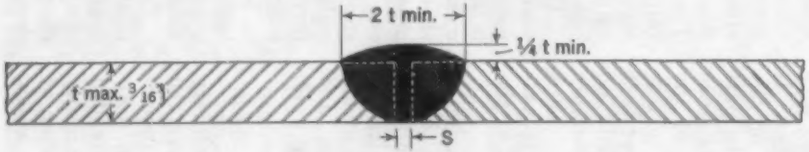


Fig. 3—Open Square Butt Weld

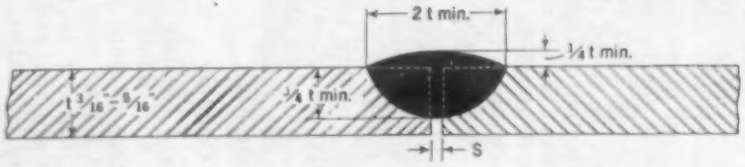


Fig. 4—Open Square Butt Weld for 3/16 to 5/16-In. Pipe Wall

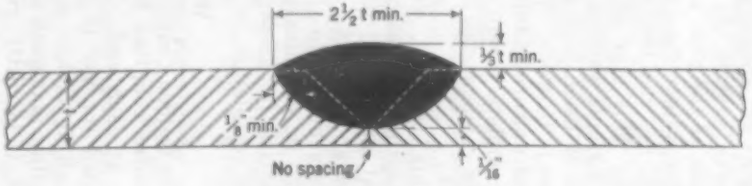


Fig. 5—Closed Single-V Butt Weld

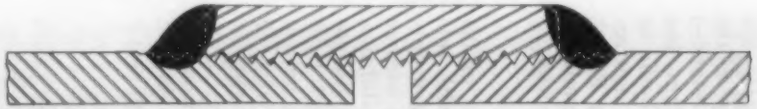


Fig. 6—Welded Coupling

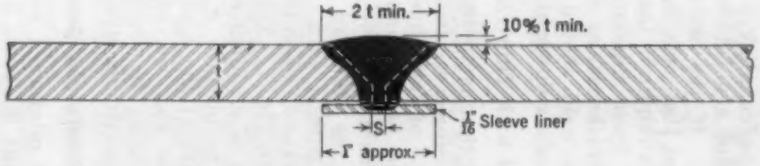


Fig. 7—Butt Weld With Thin Liner

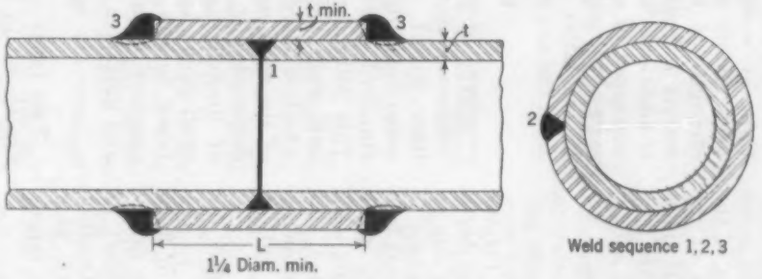


Fig. 8—Welded Bar Reinforcement

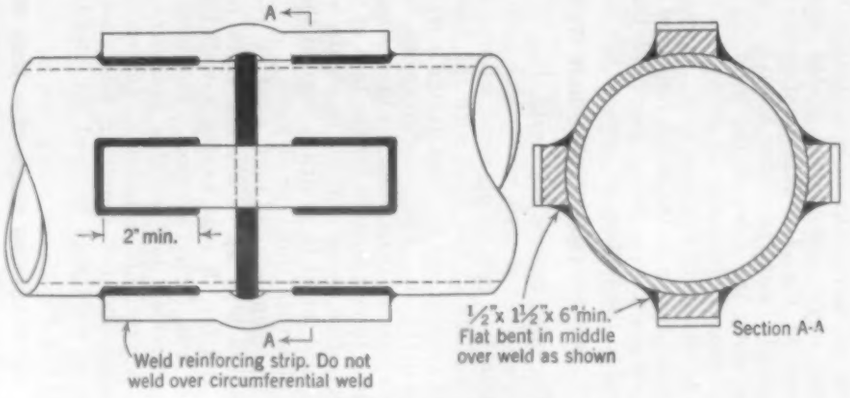

A
2" min.
A
Weld reinforcing strip. Do not weld over circumferential weld
½" x 1½" x 6" min. Flat bent in middle over weld as shown
Section A-A

Fig. 9—Welded Split Sleeve Reinforcement

struction tolerance after welding. To add an extra factor of safety, the weld is usually built up or reinforced about one-quarter of the wall thickness, as shown in Fig. 1. This reinforcement should slope gradually from the center down to the surface of the pipe along the sides of the weld. The width of the weld should ordinarily be about two and a half times the thickness of the pipe wall. In executing this type of weld, fusion to the depth indicated in Fig. 1 should be obtained, care being exercised that fusion is secured to the bottom, or root, of the joint.

Open Square Butt Weld

The open square butt weld, Fig. 3, is used for the smaller sizes of pipe, with which sufficient weld depth penetration can be obtained without beveling due to the melting of the steel with the blowpipe flame. It is in general use for pipe having a wall thickness less than 3/16 in. The reinforcement is usually made much heavier than when the open single vee butt weld is used to compensate for the lack of penetration, full penetration being difficult to obtain without allowing the weld metal to protrude beyond the inside wall of the pipe with this type of weld.

The open square butt weld is recommended for standard pipe up to 2½ in., extra heavy up to 1½ in., and for all pipe having a wall thickness of 3/16 in. or less, for all services. For some services carrying extremely low working pressures, not subject to any appreciable expansion, contraction or bending stresses and not requiring maximum strength, this type of weld may be used for standard pipe larger than 2½ in.

Closed Single Vee Butt Weld

The closed single vee butt weld, Fig. 5, is sometimes used because of certain advantages, although it is not recommended as the best practice. It facilitates lining up, especially in the case of risers where pipe lengths are simply placed one on top of the other. It insures against the formation of protrusions on the inside of the pipe and requires less skill on the part of the welder than other types of welded joints since he is not required to fuse to the inside wall of the pipe. This type of joint lends itself readily to forward ripple welding. When the closed single vee butt weld is used, pipe ends are butted together with no space in between. The sides of the vee are thoroughly fused uniformly to the depth shown in Fig. 5. Lack of complete fusion at the bottom of the vee is partially compensated for by heavy reinforcement of the weld.

This type of weld will not develop maximum strength, but does have a strength comparable to the usual mechanical joints. It may be used for pipe in sizes up to 12 in., and for pressure and service requirements up to the equivalent of saturated steam at 250 lb. per square inch. For sizes above 6-in., and especially for pressure services, reheating of the weld, upon completion, is recommended.

Welded Coupling

The welded coupling, Fig. 6, consists of an ordinary threaded coupling having fillet welds encircling the pipe at each end. This type of joint is not recommended for use in welded piping construction. Although it makes a joint superior to the threaded coupling inasmuch as it is stronger and permanently tight, it is costly, requiring a coupling, the labor of threading, the labor of tightening up and two welds. The inside of the pipe is not smooth and therefore does not have maximum flow characterstics.

The joints of existing screwed lines are often made tight by welding at the couplings. The welds are used mainly as seals but also add materially to the strength of the joint. If the welds are intended merely to seal the joint they may be very light, but if additional strength is required, the fillets should be increased in size until their dimensions are approximately the pipe wall thickness, as shown in Fig. 6. In the latter case, the weld should slope gradually from the end of the coupling down to the pipe wall.

Butt Weld with Thin Liner

A type of line joint that is in the process of development, is the open single vee butt weld with thin liner, Fig. 7. This type of joint has been used only experimentally up to the present and has not become standard, but indications are that it has possibilities. This joint consists of the standard open single vee butt weld backed up with a thin, sheet-steel liner which is fused in the welding operation to the bottom of the weld, as shown in Fig. 7. This joint has been designed with the idea of enabling even an operator of limited experience to produce a weld free from protrusions on the inside of the pipe, yet thoroughly fused to the bottom of the vee, and to enable an operator of average ability to produce more easily and quickly a weld of maximum strength.

Special Reinforced Joints

Two types of special reinforced welded butt joints are shown in Figs. 8 and 9. Some authorities maintain that reinforcements are never necessary with properly made welded butt joints, regardless of the service for which they are intended, and such reinforcements are not generally recommended; but they may be used for river crossings and in piping systems for joints known to be subjected to excessive vibration and bending stresses. The bar reinforcement, Fig. 8, is ordinarily used only for the larger sizes of pipe. It consists of straps welded across the pipe weld at intervals around the circumference. The straps are either bent or ground to fit over the reinforcement of the butt weld. To be of sufficient strength against bending the straps should be as thick as pipe wall and 1/3 to ¼ the pipe diameter in width. Spacing between straps should not be more than 8 in.

The butt weld with welded split sleeve, Fig. 9, is used for practically the same purpose as the bar reinforcement shown in Fig. 8. When this type of joint is used, a flush weld, that is, a weld with no reinforcement, is used for making the joint to be braced. A short section of pipe of larger diameter than the pipe to be reinforced is either split longitudinally on one side and slipped over the pipe for welding or split in half, placed around the pipe joint, tacked and welded longitudinally and at the ends. The reinforcings sleeve should fit closely and have a minimum length of 1¼ times the nominal diameter of the pipe to be reinforced. At least ⅛-in. space should be allowed at the bottom of the vee for the longitudinal weld (or welds) in order that the contracting of the weld metal may draw the sleeve around the joint.

To secure maximum strength in all of the foregoing joint designs, all of the butt welds should be thoroughly fused to the joint edges and should extend completely to the bottom of the vee. All fillet welds should be thoroughly fused to the root. All welds should be of sound metal throughout.

Twenty Five Years of Electrical Welding

By P. W. FASSLER

✦ This paper was presented at the March 24, 1931 meeting of the Detroit Section A. W. S., by P. W. Fassler, Manager, Electric Welding Dept., Fisher Body Corp., Detroit.

HISTORY OF WELDING

FOR centuries metals have been joined by three methods, namely: by riveting; soldering, and by welding. We know that the natives of India two thousand years before Christ were able to melt, forge and weld iron. The methods used in those times were not greatly improved until the nineteenth century.

The beginning of electrical welding dates back to the year 1865. Wilde's English Patent No. 1412 of that year demonstrated that it was possible to melt metals by means of the electric current. Fifteen years later Bernardo performed the first electrical arc weld by means of a carbon arc.

The most important revolution in regard to welding was made by Elihu Thompson in the year 1886 when he made a weld by means of electrical resistance. The patents on his methods date back to the year 1890. He demonstrated that practically all of the metals could be welded by means of his electrical resistance method.

Here we already have to deal with two different methods or processes in electrical welding, namely: the arc welding and the resistance welding processes.

Engineers were undecided as to whether the process of electrically joining metals should be called "welding" or "fusion." The circumstances, at this time, were made more complicated when the argument of acetylene or gas welding was brought up. This was because of the fact that gas welding and arc welding have a similarity of function. The electrical resistance welding process which is merely a heating and squeezing operation is, no doubt, as close to the old fire welding as the methods the blacksmiths are still using.

Finally, we came to a compromise with the understanding that acetylene and arc welding should be considered as melting processes compared to resistance welding which is a heating and squeezing process.

In using the arc or gas welding processes you can join metals only by heating the pieces to be welded to a high temperature and by the addition of other metal usually whereas, in resistance welding it is quite different because here we join the pieces of metal under pressure at the melting point without the addition of any other metal.

It is remarkable that the arc welding process, despite the fact that it was invented first, was unable to keep pace with the resistance welding during the first ten years. In the year 1907 one could speak of resistance welding as an accomplished fact while the arc welding method became popular only after its use in the World War, during which time it proved its efficiency and worth.

The first machine to be built on the application of the Thompson patents dealing with resistance welding was a Butt Welder. Then came the Spot Welder which represented an entirely different type of welding machine. Shortly after these developments were brought about, seam welding was attempted by means of a series of spots along the proposed seam of the pieces of metal to be joined. In the year 1910 the first Automatic Spot Welding Machine for such a purpose was built. At the same time Spot Welders were built with the electrodes constructed in the form of roller segments which were operated by hand. By 1912-'13 Automatic Seam Welding Machines were on the market for welding continuous longitudinal and round seams.

We now see the welding industry in the semblance of a young tree with each of its branches seemingly going their own way to a future development and perfection.

During the following years these three branches of the welding industry, which we have discussed: *Butt; Spot,* and *Seam Welding,* have each been treated separately and their fundamental principles have been proved and securely founded on successful experiment. On the basis of these experiments it was determined that each branch of the welding industry required individual and specialized attention and treatment for the successful application of the fundamental principles of electrical welding.

Our Flash Welding Machine of today represents the application of the basic principles of butt welding. This method of welding by flash was accidentaly discovered during a butt weld experiment which, due to a miscalculation, did not turn out as expected. It has been used since 1910 for welding pipes and tubes with a thin wall but could not fight its way above the other branches of the welding industry. The same fate befell the projection method of welding which dates back to the year 1909 and which is also known as relief welding. Manufacturers were not willing to take the extra trouble of embossing the metal to be welded which is necessary if you wish to use this process. Relief Welding was not recognized at that time and was used in only a very few cases because of the poor development of the sheet metal industry.

The foregoing gives us an insight into a few of the important points concerning electrical resistance welding and now, before we go into the discussion of the different methods of welding, we must be clear as to what can be welded and what welding is.

WHAT IS WELDING?

Whenever two metals of the same or similar composition are joined together so as to make a homogeneous whole we say that a weld has been performed. This weld is established by heating the parts to be welded at the joint until they become "doughy." When this stage is reached the parts are connected together by means of mechanical pressure as in fire welding or in electrical resistance welding. If two parts to be welded are brought to the melting point so that they flow together the mechanical pressure could be eliminated and the method called fusion welding like in gas welding and in arc welding.

The process of joining two metals together by means of an additional metal with a lower melting point is called soldering.

The procedure of electrical welding is so generally well known today that it is not necessary to speak further about it than to state that it is an electrical short circuit. This short circuit of which we speak, while undesirable in an electric line, is the force by which electrical resistance welding is made possible.

The conditions of current are so selected that when it is passed through the parts to be welded, which form the resistance unit of the circuit, it brings them into welding temperatures immediately. The time of heating depends entirely upon the resistance of the metal. Naturally, steel and iron having a high specific resistance are most suitable for electric welding.

This short explanation will assist us in understanding the following discourse on "How to Weld."

HOW TO WELD

There are certain fundamental thermal and electrical laws which have a vital bearing on the design of welding machines. Of these laws the so-called Joule's law of mechanical relation to heat is of prime importance and perhaps the Ohm's Law of electrical circuit is of equal importance.

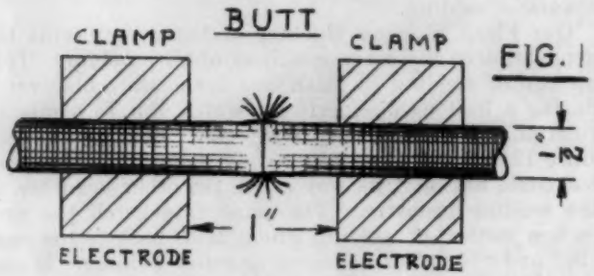
We shall list the laws in the relationship expressed above:

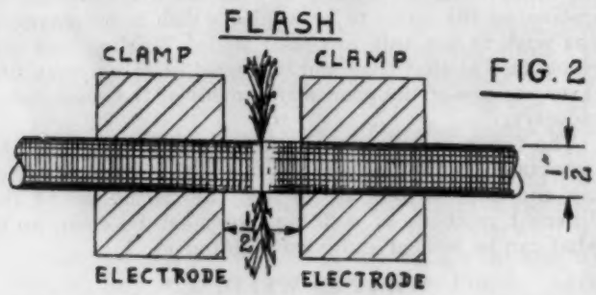
Joule's Law:

Q (quantity of heat in gram calories) = .238 IET = .238 I²RT

I = Amperes; E = Volts;

T = Time in seconds; R = Resistance in Ohms.





Ohm's Law:

$$1\ (\text{Amperes}) = \frac{E\ (\text{Volts})}{R\ (\text{Ohms})}$$

$$R = \text{Ohms for any conductor} = \frac{L \times C}{A} \text{ where}$$

L = Length; C = Specific Resistance; A = Area of Conductor.

It becomes evident that the modern electrical welding expert must be thoroughly familiar with heat transfer phenomena and must know materials.

Let us illustrate the application of these laws in a welder design.

Our problem is to weld two (2) pieces of steel one-half inch in diameter by the butt welding method. We wish to determine the size of the transformer needed and the energy consumption if the welding time be restricted to five (5) seconds.

The Electrodes are spaced one (1) inch apart at the start of the weld as illustrated in Fig. 1. This fact indicates the mass of metal we will have to heat.

In determining the weight of the pieces to be welded we get 24 grams of steel. From our hand-book we find that it would take 230 gram calories to heat one (1) gram of steel from one (1) degree Centigrade to 1400 degrees Centigrade, which is the theoretical temperature we need for welding. Experience tells us that the 24 grams of metal will not accept the heat necessary to raise it to a uniform temperature of 1400 degrees, so we take a lower average value of 210 gram calories per gram.

Multiplying our 24 grams by 210 gram calories gives us the total number of heat units we need for our weld:

$24 \times 210 = 5040$ gram calories.

We know from the Joule's Law that the conversion factor from heat units to mechanical or electrical units is: one (1) heat unit = 4.184 watt seconds.

Therefore the number of electrical units we require for welding 24 grams of steel as shown in our sketch is:

$4.184 \times 5040 = 21{,}000$ watt seconds = 21.0 kilowatt seconds.

In the above calculations we have ignored the heat losses in the transformer and in the mechanical assembly, so the values arrived at are theoretical only.

Experience has shown us that it is necessary to add 50 per cent to the theoretical value; therefore, "Q" becomes 30.5 kilo-watt seconds and our transformer must have a capacity of 30 kilowatts.

We might remark that the 50 per cent addition is a function of the efficiency of our transformers and our ability to restrict heat losses through the clamping devices, etc.

The next experiment is to weld similar pieces in a flash welding machine instead of a butt welder (see Fig. 2). In this case we know that we are going to weld much faster as we are concentrating the heat on the ends of the pieces to be welded. This gives us a chance to move the electrodes closer. The distance from the electrodes instead of one inch (1 in.) is only one-half inch (½ in.) for this experiment. Automatically the weight of the piece with which we have to deal is only one-half (½) of 24 grams or 12 grams. This suggests that we can make this weld with about 10 kilowatts and in a much shorter time than was required for the butt weld. Besides this we learn that the heat has not a chance to go through the clamps and transformer, therefore, instead of adding 50 per cent to take care of the losses we have to add only 25 per cent. In this particular case we do not have to build a machine for 30 kilowatts but only for 15 kilowatts.

This clearly points out that the flash welding method takes a considerably smaller type of machine; is able to do more in production and consumes a great deal less current. The following example will give you the cost of welding a hundred pieces.

$$\frac{\text{No. of pcs.} \times \text{kilowatts} \times \underset{\text{(in second)}}{\text{welding time}} \times \underset{\text{(in kilowatt hours)}}{\text{cost of current}}}{3600}$$

$$\text{Butt Weld:} \frac{100 \times 30 \times 5 \times \$0.02}{3600} = \$0.07103 \text{ per 100 pcs.}$$

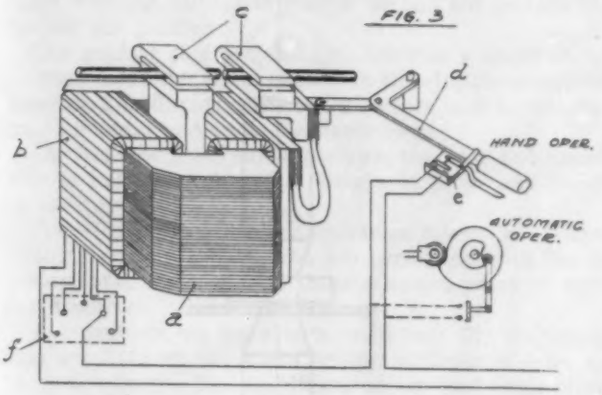
$$\text{Flash Weld:} \frac{100 \times 15 \times 2 \times \$0.02}{3600} = \$0.01667 \text{ per 100 pcs.}$$

The kind of current which is most suitable for electric resistance welding is the single phase, alternating current. The Amperage (I) is in relation with the piece and adjusts itself accordingly and is within a range of 2,000 to 15,000 amperes while the secondary voltages vary from two (2) to twelve (12) volts.

We have conclusively proved that the theory employed

in welding together the two (2) pieces of ½ inch stock in a normal 20 K.V.A. Butt Welding Machine is correct. We have shown that for the butt weld 24 K.V.A. or approximately 19½ kilowatts was required with a welding time of two (2) seconds. The flash welding experiment also proved our theory.

This short description gives us an illustration of how



the welding machine industry was developed and how we are able to weld.

BUTT WELDING

We now come to the description of the various welding groups. First, of all, we shall take the Butt Welders, an illustration of which is to be found in Fig. 3:

A. Iron Core.
B. Primary Winding.
C. Secondary Winding.
D. Hand Lever to Operate Slide.
E. Moment Switch, Hand Operated.
F. Primary Control Switch.

The mechanical design of this type of welder depends largely upon its application in production. The various types are: hand, foot, semi-automatic and automatic. The most vital parts of a butt welder, like any other welding machine, are:

A. Transformer.
B. Clamping Device and Electrodes.
C. Squeezing Device.
D. Primary Current Breaker.
E. Primary Current Control Switch.

There are various types of transformers in use today of which it might be said that they are of the highest possible efficiency. It is seldom, however, that you find a transformer built up to 500 Kilowatts.

As all of these machines have to be connected to a single phase alternating current line, it is absolutely necessary in designing a transformer to take the best of care so that the resistance on the joints and on the parts transmitting the current to the electrodes or working parts is kept to a minimum. In one of our foregoing examples we gave the fundamental reason for this.

In the last five (5) years Flash Welding has been so greatly developed that it has practically done away with Butt Welding.

However, as the Flash Welder is absolutely identical in construction with the Butt Welder is it not necessary for us to give you a better description at this time.

After this short definition we come to the questions of what is a Flash Weld and what is a Butt Weld.

During the process of making a butt weld a large amount of pressure is exerted upon the pieces to be welded before the primary circuit is closed (see Fig. 1). However, in direct contrast to this, in making a flash weld the primary circuit is closed before any pressure is exerted upon the pieces. This causes them to arc on the slightest touch of each other, as illustrated in Fig. 2.

SPOT WELDING

The origin of the Spot Welder, as we have mentioned before, relates back to the Butt Welder which it resembles quite a bit. An illustration of this type of machine is shown in Fig. 4.

The vital parts of a machine of this type, as illustrated in the above figure, are:

A. Base.
B. Secondary Winding.
C. Iron Core.
D. Primary Winding.
E. Primary Current Control Switch.
F. Lower Arm.
G. Upper Arm.
H. Moment Switch which can be either operated by hand, foot or mechanically.
I. Lower Electrode, in this case, stationary.
K. Upper Electrode Body mounted in the Upper Arm (G), movable.

This design is of great simplicity and has the advantage of being very easy to operate. The outstanding characteristics of this type is that it relates in its method (more so than any other type of machine) to the old fire welding. For example, the Lower Arm (F) can be designated as the anvil and the Upper Electrode (K) as the hammer.

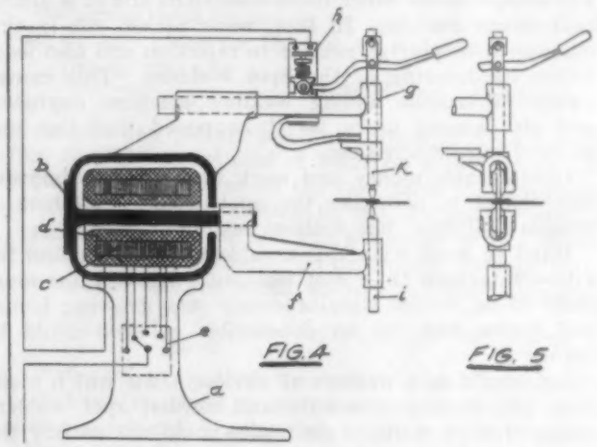


FIG. 4 FIG. 5

In comparison with the other types of welding machines, the spot welder has been very much more in favor ever since its inauguration because of its universal adaptability.

In fact, it is employed not only as a spot welder but also as a heating machine, butt welder and as a seam welder.

The electrical resistance welding method has been so highly introduced into the entire industry that, today, only special machines are being built to take care of the major group of functions, such as: spot welding, butt welding and seam welding.

RELIEF WELDING

Welding machine experts of foresight, today, are prophesying that these types of machines have found a strong rival in the electric relief welding or projection welding machine and they have deemed it necessary to clear the field for it. In order to understand it more fully we must go back to the development of the welding

machinery industry and to look into the very being of the spot welder so as to become better acquainted with the method of spot welding.

To produce a spot weld in a correct manner we have to observe the movement of the pressure controlling spring, which must be of such dimensions and adjustments and kept in such a position that the switch cannot be closed before a pressure of 80 to 100 pounds is exerted upon the welding stock. This will guarantee an absolutely dependable weld even with unclean welding stock. This pressure does not represent the total force with which the two (2) pieces are joined, in fact, the final pressure is greater but this initial force is great enough to eliminate an arc between the Electrodes and the welding stock.

In modern industry, especially in the automobile industry, the demand of tremendous speed from spot welders has changed our opinion of this type of machine of ten (10) years ago entirely.

A foot operated spot welding machine with which we make up to 200 spots a minute is not unusual and as the machine operator is paid on a piece work basis the first thing they do is to ease up the machine.

This is done through the release of the control spring which operates the switch. In many cases we found that a perfectly designed spot welder was being operated with the complete elimination of pressure.

If such an adjustment is made we will never create a good weld as we would immediately develop an arc which leads to holes or dangerous crystallizations in the welding stock. This almost uncontrollable condition will always occur under these conditions and it is almost beyond our control. In fact, work turned out in this manner is very often subject to rejection and also leads to the condemning of the Spot Welders. This caused plenty of trouble among welding machine engineers and also among users, so it happened that the spot welders were discredited.

Considerable money and work was spent to improve this condition or make the spot welding method or process foolproof, but without results.

Hand in hand with this trouble was the demand for a faster method than spot welding. The cry for more spots to be welded simultaneously was growing louder and louder and yet no dependable solution could be found.

Automatic spot welders of various sizes which made over 100 strokes a minute and normal spot welders equipped with multiple electrodes could not satisfy the demand except in only a limited number of cases and so, once again, the Joule's law came to help us in the solution of this problem.

Welding machine experts were well acquainted with the fact that the best quality of spot welding was that which was done the fastest. This was obtained by the localization of the heat.

With the so-called "Full Automatic Moment Switch," which had the tendency to close the current after obtaining the weld and then jumping out while the pressure was still on, we received very remarkable results but, however, the welding machine operators did not care for this device as they wanted faster machines.

The subject of switches is getting so very important that I am afraid that we will have to devote an entire evening to it. It seems to me that we have neglected this part of the welding machine more than anything else.

It is hard to explain the reason why the relief or projection method of welding had to wait so long before we adopted it in our production system.

Just for curiosity, we took our Fig. 6 from an A. E. G., Berlin catalog of 1911 together with the following description of this method which we wish to quote herein:

"In Fig. 21 a welding machine is shown which was built by the A. E. G. for the purpose of welding small parts to rotor discs. The relative shapes of the pieces

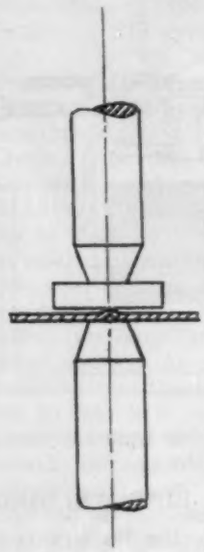


Fig. 6

to be welded can be seen in Figs. 22 and 23. As you will notice, there is a rivet-like connection to be made at the place marked "S," and on the sheet metal ring the embossments are already made. The operator first places one of the small stampings (produced out of sheet metal) upon the armature discs and the upper electrode is then made to advance toward these pieces and produce a weld.

"After welding the electrodes release the disc and by means of an indexing device this disc is turned to a position where it allows another small stamping to be placed upon it and the welding process is again repeated. This operation is continued until an entire piece is completed. The loading of the welder is limited to the placing of the discs on the machine.

"Prior to the advent of this method it was necessary to join these parts by riveting. This necessitated the piercing of holes in the discs in order to allow the rivet shank to act as the locating pin for the little sheet metal stamping to be riveted to it. Welding considerably lessened the producing cost of this operation in comparison with and to the old fashioned riveting method."

This machine was built two (2) years before this article was published and I can well enough remember that we called this method—Relief Welding. It should also make us think because of the fact that we, as the article describes, already had full automatic relief welding machines with index loading devices at that early date. This now popular method or process opened for the electric welding machinery industry and, naturally, the metal products industry unforeseen perspectives.

Today with this method we are enabled to weld an almost unlimited number of spots in a single stroke. Not only this but also the maximum thickness of the sheet metal to be welded has been increased many times, whereas, in spot welding this was very limited. Besides this it gave us the possibilities of using cheaper material having scaled surfaces, etc., with a machine relatively smaller than the spot welding machine.

The greatest advantage we attain with this new method is, doubtless, an absolutely dependable weld and the high speed with which we can figure on for our production. We do not have to depend on the welding machine operators any longer. The relief welding method is the heating process that stands in the first row of heating technic.

There is much more that could be said about spot and relief welding, but, at this time, we can not go into this matter any further.

The goal of this article is to describe a short sketch on what has been accomplished in the electric resistance welding line during the past 25 years and to put this into a popular and understandable form.

As we know from our experience the best and easiest way to explain problems is always to prove any theory on hand from an example.

Therefore, the following examples might be of some importance to all of us who are connected with the industry, and, especially, to those who are users of welding machines.

The problem we have is to weld two (2) stampings that are 3/16 in. thick and having surfaces of 5 in. x 8 in. respectively. The specifications are that these pieces are to be welded together with eight (8) spots and the required production is 300 pieces an hour. How much would the necessary welding machine outfit cost? How much labor would be required and how much would the current cost for welding 100 pieces be? The current is to be figured at the rate of $0.03 per kilowatt hour.

The Electric Welding Machine Salesman to whom we take this problem should be an expert and, therefore. should be able to help us in this matter. He would probably suggest a 50 kilo-watt machine as his experience has taught him that we need approximately 30 K.V.A. with a welding time of three (3) seconds per spot.

Let us analyze this proposition which occurs daily in our business from a closer viewpoint: In our chapter on "How to Weld" we figured the current cost in two (2) different examples, namely: Butt and Flash Welding. Therefore, we are going to use the same formula for showing the respective costs between spot and relief welding:

$$\frac{30 \times 100 \times 8 \times 3 \times 3}{3600} = \$0.60 \text{ per 100 pieces.}$$

This means that the actual current cost for welding 100 pieces with eight (8) spots each costs $0.60. In high production such as we have in the automobile industry we would get into trouble as we neglected the current that we lose in spot welding through these two (2) 5 in. x 8 in. surfaces. The first spot could, no doubt, be welded with 30 K.VA. and in three (3) seconds, but the third and the fourth spots could not be welded at these figures and the fifth spot would show a reading on our wattmeter of over 50 K.W. and a required welding time of five (5) seconds. It is taken for granted in these statements that the electrodes are in good shape. Suppose, to be liberal, that we take an average of 40 K.W. with a welding time of four (4) seconds instead of three (3) and we would get the following cost:

$$\frac{40 \times 100 \times 8 \times 3 \times 4}{3600} = \$1.07 \text{ per 100 pieces.}$$

Closer control of current costs is already an established fact in our institution, but in the future it will be of even greater importance.

In neglecting the true picture which occurs in spot welding we would be shy approximately $0.40 per 100 pieces or $4.00 a thousand on current cost alone. We also learn that a 50 kilowatt machine would be far too weak for this purpose. Now propositions like this or what we would call "misrepresentation" did not increase the popularity of the spot welding process any, as we have told you before.

We production men have to depend on the advice we get from the welding machine experts and from the experience that the welding machine industry has accumulated in these many years. Therefore, in buying a welding machine today it is still a matter of confidence, at least, until we get more information and facts from our welding machine experts.

We will now take the matter to another welding machine company, but their salesman knows more about the fundamental principles of welding. He knows, as we have already mentioned, that the best weld is always the fastest and, possibly, he knows something about heating theory and technic. He, let us assume, proposes a relief welding machine instead of a spot welding machine. Furthermore, he knows the advantages of the full automatic switch which we spoke about in our chapter on "Spot Welding" and with a motor driven machine it would have all of the required characteristics, but it would cost more than a normal spot welder. Also, it would be necessary to emboss one of the two (2) stampings, but this would not cost any extra money and it would enable us to weld all of the eight (8) spots in a single operation, which means that this is eight (8) times faster than spot welding. We also trust him when he says that it would require only 150 to 175 kilowatts to weld all eight (8) spots in one stroke with a welding time of only one (1) second.

We again check up on our current cost, as we did not care so very much for the last example, and we get:

$$\frac{100 \times 175 \times 1 \times 3}{3600} = \$0.15 \text{ per 100 pieces.}$$

As you can plainly see, this would give us a reduction on the current cost of $0.92 on a 100 pieces. Experimental work done on the very same job covers, in a liberal way, this theoretical figure. In making some experimental welds we had 150 kilowatts with a welding time of one (1) second. To determine the final cost of current for the 100 welds we received the following:

$$\frac{100 \times 150 \times 1 \times 3}{3600} = \$0.12 \text{ per 100 pieces.}$$

Now, we know that we can go ahead with a clear conscience as there is no longer any question of how many machines are needed to give us the required hourly production, because we now know that one (1) machine can take care of same very easily. We also know that the quality of the welds is much better than with a normal spot welder as we do not have to depend on the welding machine operator any longer, as the automatic machine takes care of the weld entirely.

All this goes to prove what a tremendous improvement relief welding is. In our calculations we still neglected a very important item. In order to produce good spot welds as required in the automotive industry it was necessary to use cold rolled steel, but with the relief welding process we can ignore a thing like that. With this process we now can weld once-passed steel as well as cold rolled steel, and in many cases we prefer the once-passed material.

That welding machine salesman, in whom we have plenty of reason to have confidence, surely would not neglect to figure out such an important point. So, therefore, he will show that the weight of the material for this stamping is three (3) pounds. And, the cost of cold rolled steel is $3.40 per hundred pounds and the

cost of once-passed steel is $2.15 for a hundred pounds. In other words one part, weighing three (3) pounds, costs $0.1020 for cold rolled steel, whereas the same part would only cost $0.0645 for once-passed steel. Therefore, without figuring scrap we save $0.04 a piece or $4 a 100 pieces.

After knowing more about the secret of the relief welding process we can more fully understand the reason why the spot welding processes are being taken over by the relief welding method. With this new method it gives the welding machine designer much more opportunity to show his skill than was ever dreamed about before.

There are a number of relief welding machines today that are producing 2000 parts an hour with approximately 12,000 spots. We cannot afford to neglect facts like these and we have to give plenty of credit to the American resistance welding engineers for what they have accomplished in the last five (5) years, which was much more than in the previous twenty (20) years. We regret that this young industry has not a better way or means of telling the world what it has done and what it is able to do. We read very little about what it produces and of its achievements in comparison with the other welding methods.

There are not enough men yet who realize what this young industry has done for the whole American metal industry and who have seen this from a national viewpoint.

SEAM WELDING

We now come to the third class or group of welding functions, namely, Seam Welding. As we have mentioned above, Seam Welding is the last limb or branch on the young but already strongly developed tree of resistance welding.

It is like the youngest child in the family with all of the characteristic weaknesses, advantages and disadvantages.

We know that electrical welding veterans will agree with us when we say that there was more time and money spent on the development of this line than in any other.

It would be worth while to write a little book on this subject, but our time here is too short to go into this matter deep enough.

In Fig. 5 we are shown the principle of Seam Welding. It does not interest us much whether the rollers are hand or mechanically driven. The electrical resistance seam welder works by making a continuous line of spots, the same as in the spot welding method, except that it has roller electrodes, which under low voltage and certain pressure, roll over the seam making the weld.

In this way we bring the overlapped joint to the melting point and squeeze it together. We can already see that we will have to deal with the same trouble as we experienced in the electrical spot welding process except in a much more unfavorable way.

Uneven surfaces, which occur on the sheet metal edges, lead to different current characteristics, such as the under or overheating of the metal in different spots.

Scaled surfaces, which have already caused us so much trouble in spot welding, bother us more here and are to blame for the conditions which we find in our seam welders today.

We have always tried to be less dependent upon the surface conditions of the metals and have tried to hold down the wear on the roller electrodes to a minimum besides obtaining the highest possible speed. Not only this, but we have tried to weld heavier stock up to ¼ in., but with the original method, as described above, we were not successful. Knowing that we obtained much better results in welding a seam with an automatic spot welder led us to the idea of dividing a continuous seam into a roller with a number of spots very close together and with a very short interruption. After every weld we made the roller moved ahead approximately ⅛ in. during which time the current was interrupted.

We called this the roller step process. It was a tremendous relief for us, but we had to realize, very soon afterward, that this process was too slow and the machines were too complicated. Not only this but also it was impossible for us to make these machines simplified and foolproof.

About this time, we came out with the so-called "intregal" process. A machine of this type was equipped with a roller electrode in the lower arm and the upper arm was built the same as a regular spot welding arm with a standard electrode tip. This method gave us 350 spots a minute and was a very promising process, except that the speed required could not be obtained.

The so-called "Pilgrim Step" process was, possibly, the nearest to an ideal proposition, but it was even slower than the roller step process.

The Agnew Patent of August 2, 1913, is, perhaps, the greatest revolution in this line in the last few years.

Agnew interrupted the current, as we have mentioned, except that the rollers on his machine moved continuously while he interrupted the current at the rate of about 600 times a minute. With this method we were able to produce approximately 950 feet of seam on 24 gage sheet metal whereas, with the intregal, roller step or pilgrim step process we were not able to get a speed of more than 350 feet an hour.

However, anyone who has dealt with heavy current interruptions, knows what it means to design an interrupter able to interrupt over 100 amperes 600 to 700 times a minute.

Nevertheless, we were able to weld almost as fast as without an interrupter and the seam was better and more dependable. We had some new trouble, though, and it was with the interrupter, itself. The reason for this was because the contacts of the interrupter would wear through and develop a flash on every interruption, thereby causing us much trouble. Therefore, lately we tried to reduce the speed so as to overcome this trouble.

Experiments to eliminate this source of trouble by increasing the contact area and by adjusting the contacts very closely (approximately 1/16 in.) were successful and in this manner we, virtually speaking, entirely eliminated the flash or spark as soon as the sine curve went through the zero line.

There are a great many new ways and patents which might lead to good results, but, as mentioned before, our time here is too short to discuss all of these questions tonight.

Experience has taught us that when welding 26-gage material without using an interrupter we obtained a better weld by speeding up the roller electrodes.

We thought that this may have some influence in reaching the zero point in the sine curve. This may sound rather paradoxical, but later on, in trying out an experiment on 20 gage sheet metal and using 25 instead of 60 cycles, we found that we were right.

There is no doubt about it that the lower the frequency is in the primary line the nearer we come to

the artificial or mechanically current interruption without, however, facing the trouble of an interrupter or of slowing down the speed.

Facts like these automatically led us to the idea of designing a special interrupter to be synchronized with the sine curve in an alternating current line.

With the proper device we could interrupt the current constantly at the zero point in the sine curve where there is practically no current. Consequently, we knew that we could build a small switch without having any trouble with arcs and that we would receive the best characteristics of a seam weld. Not only this, but it is doubtless that the current could easily be reduced 50 per cent. This means that we could again build smaller seam welding machines.

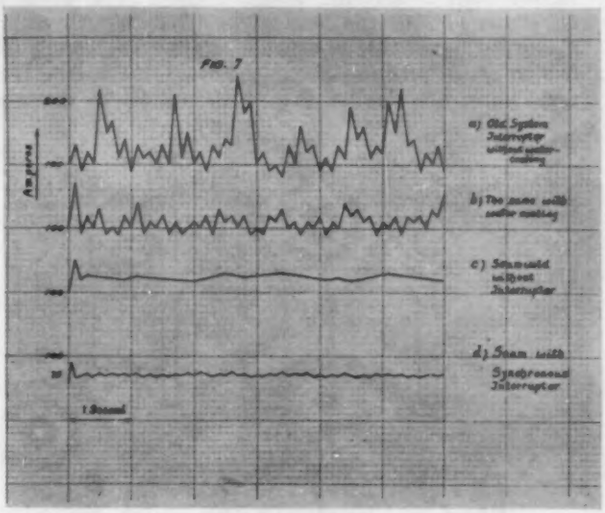
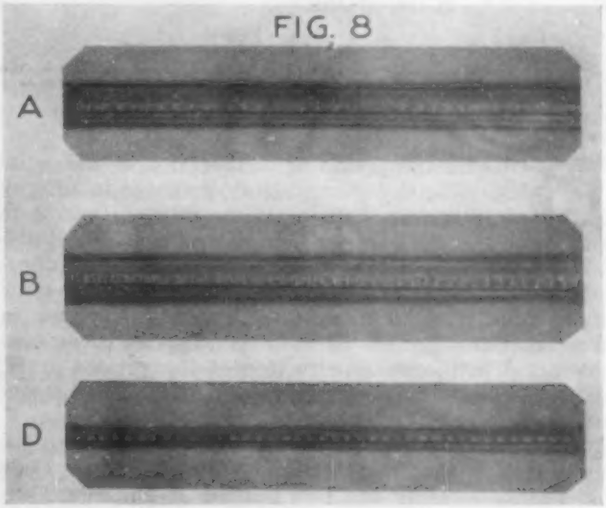


Fig. 7



We did some experimental work in this line which was very surprising as shown in Fig. 7. The amperage reading in Curve "A" registered what we got in welding a 30-inch piece of 20-gage sheet metal with an interrupter making 600 interruptions a minute and with the electrodes welding at a speed of 105 in. a minute. We started right out with a load of approximately 140 amperes and had a variation of almost up to 250 amperes. In welding this experiment we used an interrupter without water cooling.

In Curve "B" we had the same conditions except that here we welded with an interrupter with water cooling which gave us a chance to control and eliminate the arc to a certain extent.

Curve "C" illustrates the same experiment except that this time we welded without an interrupter.

Finally we come to Test 4 or Curve "D," wherein we used the above mentioned Synchronizer.

In connection with these various curves, we see, as depicted in Fig. 8, the welded samples obtained from these experiments.

In Fig. 8, "A" and "B" are both characteristic of a wide stripe in comparison with "D," which was welded with the Synchronizer. Here again we see the influence of the Joule's law.

We are very sorry that we must come to an end, at least for this evening, but before closing we wish to express our reasons for writing this article.

For years the writer has been asked countless times by younger men where can they get some literature on electrical resistance welding and has been unable to give them a satisfactory answer.

Why is this? Are the welding veterans afraid of telling the world what they know or don't they want to take the time?

There cannot be any excuse for this condition as it is our duty to give the younger generation all of the information that we have at our command. Not only do we owe this to the men connected with this line but also to every Plant Manager, Superintendent, General Foreman, Foreman and right down to the operators themselves, so that they will know what welding is: how we can weld and why we weld.

The Electrical Resistance Welding Industry is already a much larger industry than the world realizes.

In 1929 there were approximately $7,000,000 worth of electrical welding machines which were built and delivered by the Electrical Resistance Welding Industry, without counting over $2,000,000 worth of welding machines which were built by private industries. Data of this magnitude is impressive in itself and invites further analysis.

We are perfectly in accord with Professor Adams, who in the last fall meeting of the American Welding Society, said:

"There is certainly room for work in this field. Moreover, there are many important applications of resistance welding which have never been brought to the attention of the Society, and many places where new applications may yet be made.

"Perhaps many of those present do not realize how much resistance welding is now being done. As a matter of fact, the total cross-sectional area of joints welded by this process every day in our industries probably exceeds that of those welded by the arc process."

In a recent article in a European welding magazine we found the following quotation:

" . . . As the first pioneers in electrical resistance welding on this continent we have to include the names of four (4) men."

However, we do not feel that it is right unless we give full credit to the American contemporaries of these men for the accomplishments and tremendous advancements which they have achieved in this field.

Therefore, we feel that just credit for the remarkable advancements of electrical resistance welding should be bestowed on such men as: McBerty, Henke, Woofter and Taylor.

Some Tests of Gas Welded Structural Joints

Reported by **H. H. MOSS**

✦ This paper was presented at the Annual Meeting of the A. W. S., April, 1931, by H. H. Moss., Engineer, Development Department, Linde Air Products Co.

DURING the period of deliberation of a Special Building Code Committee[1] appointed in 1929 by former Mayor Boles of the city of Detroit to undertake the work of revision, desirable to the Building Code of that city, it befell the Oxy-Acetylene Industry to provide examples of structural gas welding for the observation of and testing by the Special Committee, in order that this process of welding might be given consideration in the welding section of the revised draft, along with other welding processes suitable for the construction of steel for buildings.

This requirement, while on the face being quite singular in view of the promulgation of Code I, Part A, Code for Fusion Welding and Gas Cutting in Building Construction, by the American Welding Society in 1928, lack of local precedent for structural gas welding, warranted, in the opinion of the Committee, a reasonable degree of demonstration.

The requirement of the Special Committee as to character of gas welded examples, as reported by the Consulting Engineer[2] to the Committee, consisted of three structural joints.

One: A typical seat for a beam supported upon the face of a column.
Two: A full strength splice in an average size floor beam.
Three: A side fillet welded tension bar splice to develop the full strength of two joint bars.

It was a further requirement that the specimens be welded by one or more local welders, mechanics who might be utilized on local welded constructions.

These general conditions necessitated the employment of Procedure Control methods, fully applied and at the same time providing an opportunity to demonstrate the practical side of the problem of regulating applied structural gas welding from the standpoint of safety in construction.

It being convenient and agreeable to the interests involved, the writer's company undertook the direct responsibility of developing specimens to meet the requirements of the Committee.

The designs offered to, and subsequently approved by the Committee, are shown on the following Figs. 1, 2 and 3. All welding design for specimens, for both the qualification of welders and for the Committee tests, were made in agreement with the recommendations of the American Welding Society's Structural Welding Code.

The design analysis employed for each and upon which the details of design were determined follows:

[1] Messrs. John M. Donaldson, Chairman; Henry J. Brennen, L. R. Hoffman, F. Gardner Legg, Wm. P. Zabriskie.
[2] Mr. Frank Burton.

For Fig. 1. An assumed safe loading of 12,000 lb. for each seat determined approximately 2 in. in length for the welds securing the seat angle to the face of the columns. A short weld length was desirable in view of the Committee's objective; viz., that of testing weld metal rather than base metal. For the conditions, the unequal angle is preferable. By trial, a 3½ in. x 2½ in. x 7/16 in. angle was found desirable. The conditions of loading for the angle are shown in Fig. 4—(a), (b), (c) and (d).

The total length of weld required for direct load = 12,000/3500 = 3.43 in., which, divided by 2, gives 1.72 in. either side of the seat angle. This length must be increased to provide resistance against the forces tending to cause rotation about the weld due to the eccentricities of the applied load with respect to the welds.

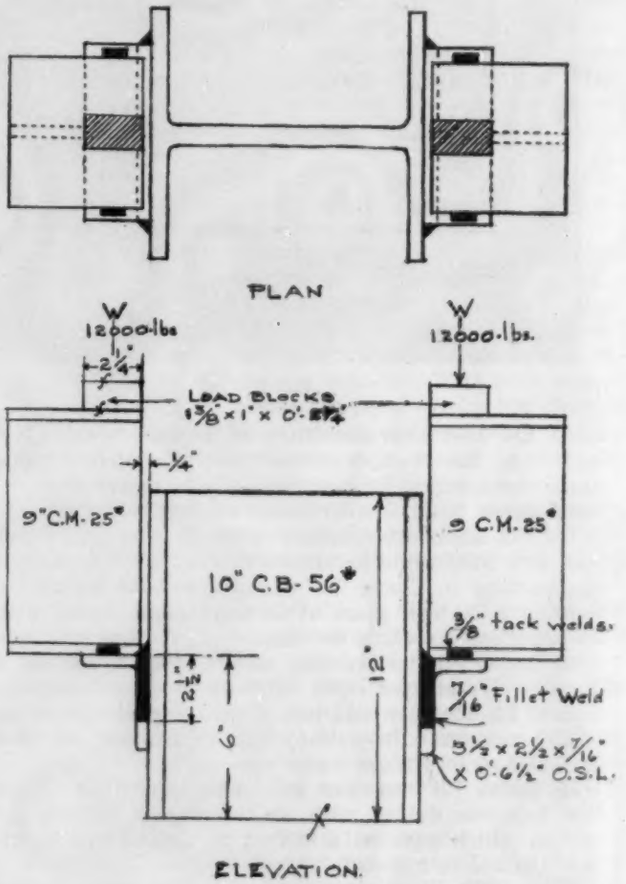


FIG-1.

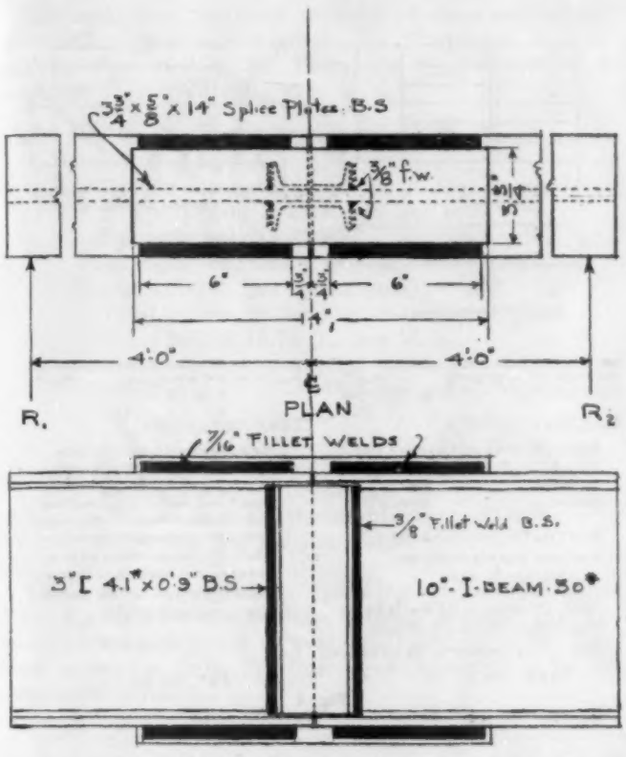
Beam to Column Connection

The tensile stress along the root of the angle acting parallel to the face of the column was considered to be amply provided for by that increment of the fillet weld extending above the upper surface or the landing plane of the angles as shown at T Fig. 4 (a).

Therefore, the welds were investigated, other than for direct shear, for strength to resist the turning force "Wy" Fig. 4 (b).

The designed dimension of the throat of these welds below the top surface of the angle is shown in Fig. 4 (d).

The bending moment upon each weld from Fig. 4 (a) and (b) = 12,000 × .575 in./2 = 3450 in. lb.,



ELEVATION

FIG. 2

Beam Splice

and, therefore, the stress at the upper terminals of the weld must be investigated to see that its intensity does not exceed the allowable fiber stress for combined shear and tension which, for the case, was taken at 13,000 lb./sq. in. The center of rotation was considered to be at ½ the width of the vertical leg as shown in Fig. 4-(d). Therefore, the distance between the assumed center of rotation and the remote fiber in tension = 1.75 in. From the foregoing data, the stress p in the weld metal at the top surface of the angle due to the turning force can be found from the formula

$$p = \frac{Mv}{I_{x-x}}$$

where M = Bending moment in inch pounds

v = Distance in inches of extreme fiber from the assumed neutral axis.

I_{x-x} = Moment of inertia of the throat section of weld about the assumed neutral axis.

Substituting the values derived:

$$p = \frac{3{,}450 \times 1.75}{.595} = 10{,}150 \text{ lb./sq. in.}$$

The average shearing stress per sq. in. upon the throat of the weld = ½ of the load W divided by the designed throat area = 7,775 lb./sq. in.

In determining the resultant stress intensity at the remote fibers of the designed welds, the stress due to bending was considered as a shearing stress of equal intensity acting in the plane of and coincident with the throats of the welds.

The resultant stress intensity at the remote fiber P_r was then calculated by taking the vector sum of the two intensities:

$$P_r = \sqrt{10{,}150^2 + 7{,}775^2}$$

$$= 12{,}800 \text{ lb. approximately}$$

which being slightly under 13,000 lb., the welds were considered satisfactory for the loading indicated.

As to the 9 in. C.M. 25 lb. I-Beam, it was found by investigation to have a safe end reaction of approximately 12,350 lb. This value was arrived at by taking 75 per cent[3] of the value resulting from the formula

$$R = F_b \times t \left(a + \frac{d}{4} \right)$$ See Note 4 below

recommended for beams with unsupported webs.

The width of the load blocks used to transmit the load from the upper platen of the testing machine to the beam stubs and likewise the subsequent extension blocks[5] was in agreement with the dimension "x" Fig. 4-(c).

For Fig. 2. For this test, a 10 in., 30 lb. I-Beam (Std. mill section) 9 ft. 6 in. long was cut in two at the center and spliced to redevelop the full strength of the beam.

In determining the splice, the stresses due to bending were considered as carried by the flanges. By investigation, the average flange stress was found to be 15,800 lb. per sq. in.[6] approximately. In calculating for average flange stress, the given flange was, for simplicity, transformed into a rectangle of equal width and equivalent area, whose remote fiber coincided with that of the original flange.

The net flange area neglecting fillets = 2.435 sq. in.

The total stress carried by the flange then = 2.435 × 15,800 = 38,500 lb. and the required area for each splice plate = 38,500/16,667 = 2.31 sq. in.

As the width is determined at 3¾ in. in order to provide space for the fillet welds inside the edges of the flanges, the thickness of the splice plates = 2.31/3.75 = .615 in. A − ⅝ in. plate thickness was adopted.

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[3] Account extreme short length of the beam stubs.

[4] Carnegie Handbook.

[5] Extension blocks, 2¼ x 1⅝ x 8 in. long, were employed to transmit load to the seat angles after the 9 in. beam stubs had failed by web buckling and were removed from the seats. See Fig. 5.

[6] F_c for a ratio of $20 \frac{1}{b}$ = 16,667 lb. per sq. in. when using F_c maximum = 18,000 lb. per sq. in. @ $15 \frac{1}{b}$. Therefore, the unit flange stress at the inside face of the equivalent flange = $16{,}667 \times \frac{4.49}{5.00}$ = 14,950 lb. approximately and, therefore, the average flange stress approximates $\frac{16{,}667 + 14{,}950}{2}$ = 15,800 lb. per sq. in.

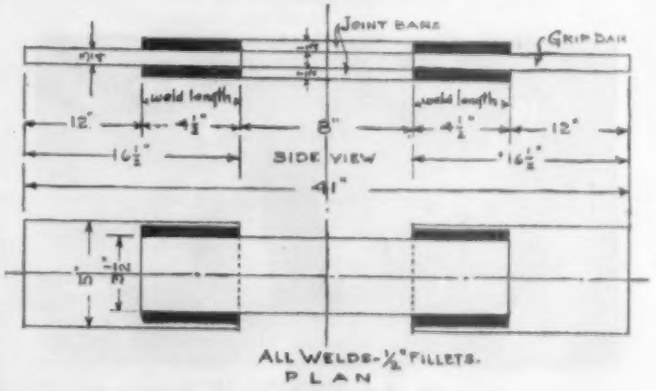


FIG. 3

Tension Bar Splice

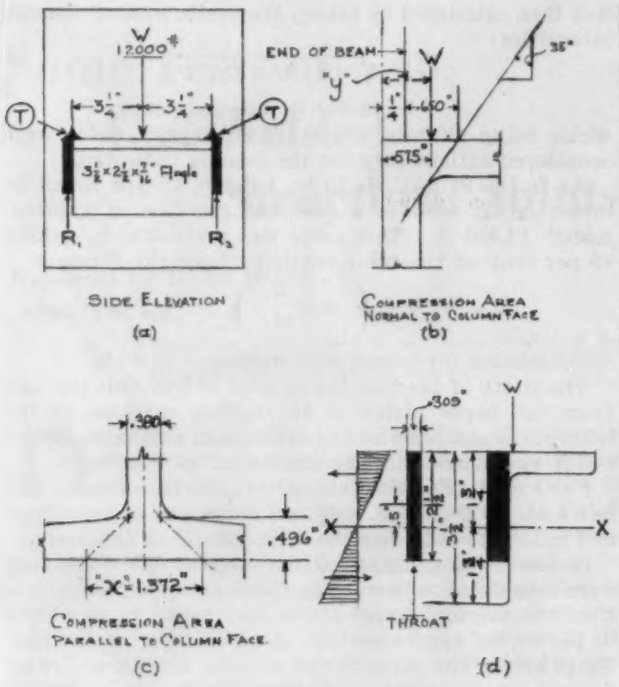


Fig. 4

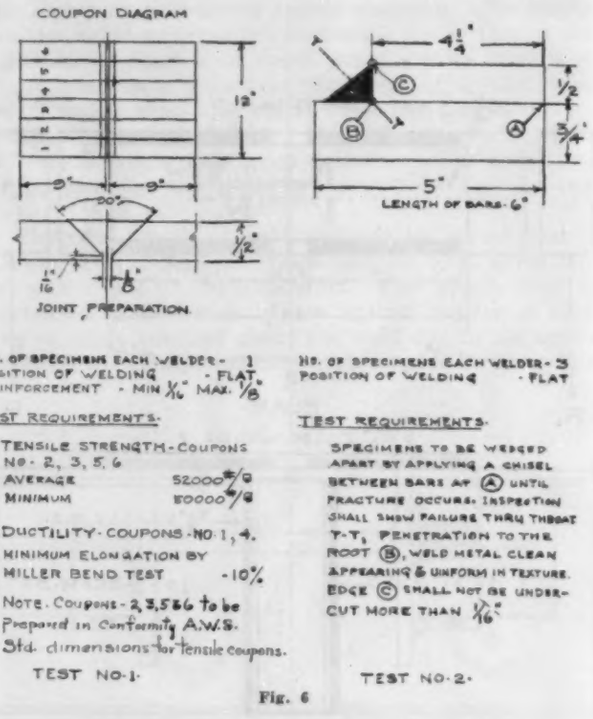
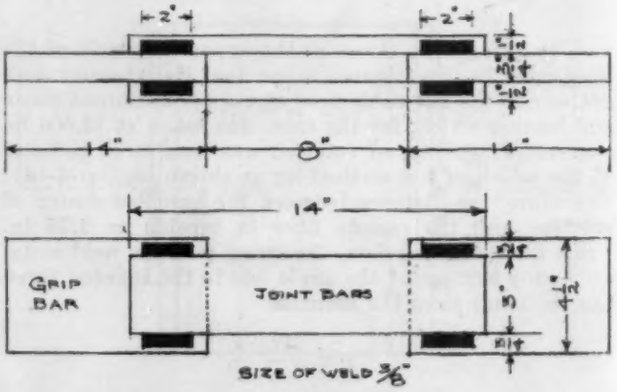


Fig. 6

In selecting the size of fillet welds for the specimens, the designed throat dimension was taken as the thickness of the edge of the beam flange, which for a 10 in. Std. Mill Section = 0.31 in. This was in order, due to weld reinforcement about the edge of flange customary when welding sections of these dimensions. Therefore, the strength of fillet weld per linear inch = 0.31 × 11,300 = 3,500 lb. Number of inches of weld required each side of center line of joint = 38,500/3,500 = 11 in. or 5½ in. each side. Six in. was used. About the center of the splice, the welds were kept ¾ in. from the end of beam to prevent possibility of transfer of stress across flanges, instead of through splice bars. Therefore, the length of splice plates required = 2 (6 + .75) = 13.5 in.

Two 3 in. — 4.1 lb. channels were fitted between flanges symmetrically about the center line of joint and welded as shown to prevent failure of the web during the test. The ⅜ in. welds either side of these channels more than restored the web strength. Two splice plates were used merely to enable setting up the beam under the most favorable conditions as to straightness of top flange. Otherwise some credit for the compressive strength of the original beam section above the neutral axis could have been taken and the top splice in consequence materially reduced in length.

Fig. 5—A Reassembly of Testing Set-Up for Specimen Fig. 1, Showing Method of Loading Beam Seats After 9 In. C.M. 25 Lb. Beam Stubs Had Failed (a)—3½ x 2½ x 7/16 In. x 0 Ft.-6½ In. Seat Angle. (b)—2¼ x 1⅝ x 0 Ft.-8 In. Extension Block. (c)—(In. x 1½ In. x 1-Ft. 4 In. Spanner Block



NO. OF SPECIMENS EACH WELDER - 2
POSITION OF WELDING - FLAT.
WORKING STRENGTH OF SPECIMEN.
WELDS - 4(3000×2)@11300#/□" = 24000#
JOINT BARS - 2(.5×3.0×16000) = 48000#
GRIP BARS 0.75×4.5×16000 = 54000#

PROBABLE WORKING STRENGTH OF WELDS-
ACTUAL WELD LENGTH = 2½"
AVERAGE SIZE OF WELD = ½"
CORRECTED WORKING STRENGTH
= 4(4000×2.5) = 40,000#

TEST REQUIREMENTS
AS DESIGNED (24000×3.5) = 84,000#
AS CORRECTED (40000×3.5) = 140,000

TEST NO-3

Fig. 7

The maximum resisting moment of the beam ($f_s S$) = 16,667 × 26.7 = 445,000 in. lb. Therefore, R_{max} = 445,000/48 in. = 9,275 lb. Therefore, W_{max} = 9,275 × 2 = 18,550 lb. approximately.

For Fig. 3. Strength of joint bars (3½ in. × ½ in. × 1 ft. 5 in.) A = 1.75 sq. in.
Tensile strength at 18,000 lb./sq. in. = 1.75 × 18,000 = 31,500 lb. per bar.
For both bars = 31,500 × 2 = 63,000 lb.
Strength of welds (½ in. fillet welds s = 4,000 lb. per linear inch).
Total inches in welding required = 63,000/4,000 = 15.75 in., use 16 in.
Inches of weld per joint = 16/4 = 4 in. net or 4½ in. gross to allow for endings.
Strength of Grip Bar (5 in. × ¾ in. × 1 ft. 4½ in.) A = .75 × 5.0 = 3.75 sq. in.
Tensile strength at 18,000 lb./sq. in. = 3.75 × 18,000 = 67,500 lb.
This exceeds the design strength of both the welds and the joint bars.

These data suggested the following qualification tests Figs. 6 and 7, for the welders, it being assumed that no qualified welders would be available for these tests. The base metal for these specimens was specified to be of structural grade.

Test No. 1 (*Continued*)
Ductility Observations—Coupons No. 1 and No. 4

Welders' Identification	Coupon Number	Per Cent Elongation in Welded Metal
P	1	17%
	4	9%
B	4	17%
T	1	19%
	4	10%

Fig. 8—Specimen Fig. 1 After Testing. Typical Failure of the Webs of the 9 In. Beam Stubs is Shown at (d). The Amount of Bending if the Seat Angle is Visible Along the Lower Edge of These Angles. Points Designated (e) Locate Detail Fractures in Weld Terminal at Total Load of 128,360 Lb. or 64,180 Lb. Per Seat

QUALIFICATION TEST RESULTS

Base Metal Properties[7]

	Spec. No.	Size	Yield Point, Lb. per Sq. In.	Tensile Strength, Lb. per Sq. In.	Per Cent Elongation, 2 In.	6 In.	Per Cent Red. Area	Fracture
	1	.506	45,300	63,700	38.5		64.8	Partial cup and cone; silky
	2	.506	45,300	64,200	39.0		64.4	2/3 cup and cone; silky
(Long)	3	1.500×.495	34,800	57,500	53.0	33.6	64.0	Silky
(Short)	4	1.500×.375	38,600	61,200	50.0	31.7	64.5	Silky

Results of Test No 1[8]. Fig. No. 6

Welders' Designation	Coupon Number	Area	Yield Point, Lb. per Sq. In.	Ultimate Strength, Lb. per Sq. In.	Location of Fracture
P	2	0.7344	36,350	53,750	In weld
	3	0.7358	35,445	54,098	In weld
	5	0.7364	35,021	59,452	In weld
	6	0.7276	36,078	50,222	In weld
B	2	0.7290	35,635	51,870	In weld
	3	0.7294	36,840	42,244	In weld
	5	0.7235	36,795	42,940	In weld
	6	0.7189	37,125	47,079	In weld
T	2	0.7275	37,580	53,960	In weld
	3	0.7476	34,643	48,440	In weld
	5	0.7275	34,643	59,615	In weld

Welder "P" qualified in this test, averaging 54,380 lb., and maintaining a minimum strength above 50,000 lb. per sq. in.

Welder "B" failed to qualify in both average and minimum unit strength.

Welder "T" averaged 54,000 lb. per sq. in., but fell a little under the minimum strength required.

Note: In explanation of the range in unit strength between the several welders, it is remarked that none of these applicants had any previous experience in structural gas welding.

[7] Test reported by Union Carbide and Carbon Research Laboratories, Inc., Long Island City, N. Y.

[8] As tested and reported by The Forest City Testing Laboratory Co., Detroit Branch.

Test No. 2. *Fig. No.* 6.

Observation of Fractured Fillet Welds

Welders' Designation	Coupon Number	Remarks	Estimated Value
B	1	Weld metal quality fair. Some indications of over heating, ends not well fused to legs, penetration ⅛″ shy, one spot 1½″ in length less than 50% fused, average throat dimension ⅜″, horizontal leg long.	Poor
	2	Weld metal quality satisfactory, average penetration to within ⅛″ vertical leg fusion spotty. Average throat satisfactory.	Poor
	3	Average throat dimension 5/16″. Penetration to within 1/16 to 1/8.	Good
P	1	Poor fusion and penetration. Weld metal good.	Poor
	2	Poor fusion and penetration. Weld metal good.	Poor
	3	Average leg fusion approximately 75%. Weld metal quality, good.	Poor
T	1	Fusion good, penetration to 1/16″. Weld metal quality satisfactory. Average throat dimension ⅜″.	Good
	2	Fusion good, penetration to 1/16″. Weld metal quality satisfactory. Average throat dimension ⅜″.	Good
	3	Same with exception of slight reduction in throat dimension averaging approximately 5/16″.	Good

Test No. 3[9]. *Fig. No. 7.*

Welders' Designation	Specimen Number	Ultimate Load, in Pounds	Remarks
B	1	142,060	Left strap was bowed so that right side carried excess loading.
P	1	130,480	Failed at weld.
T	1	145,410	One strap tore where steel cross-section was reduced because of excess melting, simultaneous with failure of weld on opposite side.
T	2 (extra)	148,400	Failed at weld.

A review of these data designated Welder "T"[10] as most suitable and this welder was subsequently employed to weld the Test Specimen for the Committee, but not before being given additional training in order to correct conditions responsible for the slightly low strength of his coupon No. 3 in Test No. 1.

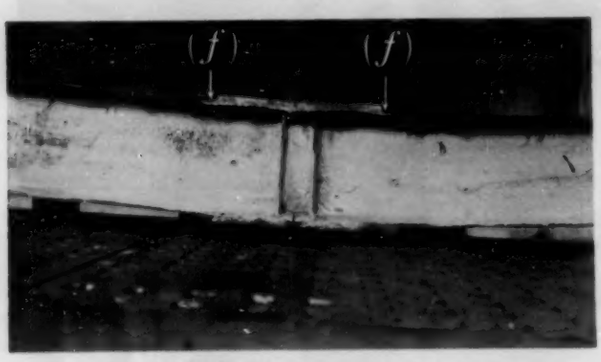


Fig. 9—Specimen 2 After Failure Occurred by Detail Crippling of Compression Flanges Just Beyond the Ends of the Splice Bar as Shown at (f)

Fig. 10—Specimen 3 After Failure Occurred Showing Location of Fracture at (g) in the Joint Bars Adjacent to the Inside Terminals of Fillet Welds, at Total Load of 196,930 Lb.

The welding of the Committee's specimens followed and was conducted in the presence of members of the Committee. At the completion of welding the specimens were forwarded to the testing laboratory operated by the City of Detroit to be loaded to destruction. The results of these tests follows:

Results of Tests Made by Committee:

(Note: These specimens, Nos. 1, 2 and 3, were painted with a thin coating of cement for purpose of aiding in the interpretation of tests.)

[9] As reported by Forest City Testing Laboratory Co.
[10] W. J. Thomas Welding Company, Detroit.

Figure No. 1

Working load per bracket	= 12,000 lb.
Max. load	
Beams 54,500/2	= 27,250 lb.
Beam seats 128,360/2	= 64,180 lb.
Factors of Safety	
Beams	= 2.27
Beam seats	= 5.35

Remarks

@ 37,500 lb. total load, first indication of yielding in the webs of 9" beam stubs.

@ Total load of 54,500 lb., the beam stubs which had been tack welded to the seats, failed by web buckling, as shown in Fig. No. 8 (d). These beams were removed and extension blocks placed upon the seats and the loading resumed. The load was increased gradually until at 128,360 lb. no further load could be applied due to detail fractures occurring in the upper terminals of the welds, shown at (e) Fig. No. 8, which allowed the brackets to deflect between welds.

Fig. No. 2.

Working load	= 18,550 lb.
Maximum load	= 77,270 lb.
Factor of safety	= 4.17

Remarks:

First indication of yielding occurred in the top flange just beyond the ends of the splice bars and at a total load of 47,000 lb.

At 77,270 lb. total load, the specimen had reached its maximum strength, failure occurring by detail crippling of the compression flanges, just beyond the ends of the splice bars at (f) Fig. 9.

Fig. No. 3.

Working load of joint bars	= 63,000 lb.
Maximum load (joint bars failed)	= 196,930 lb.
Factor of safety	= 3.13
Average ultimate stress developed in joint bars	= 56,300 lb.
Average maximum strength per actual linear weld inch at point of failure of joint bars	= 11,000 lb. *approx.*

Remarks:

Failure occurred in the joint bars immediately adjacent to the inside terminals of the welds in the upper half of specimen (see Fig. 10). Inspection disclosed undercutting of base metal, due to melting during welding, at the origin of break in upper joint bar.

At 119,000 lb. total load, uniform yielding of joint bars occurred as evidenced by flaking of cement coating. No other evidence of yielding at this load.

At 139,000 lb. total load, indications of yielding at the inside terminals of welds.

At 149,000 lb. total load, yielding progressing toward the center of all welds.

At 159,000 lb. total load, yielding general in joint bars and welds.

At 196,930 lb. total load, specimen ruptured as noted above.

Conclusions:

1. Aside from proving the feasibility of structural gas welding for the range of construction embraced in these tests, this episode again demonstrated the dependability of Welding Procedure Control from the standpoints of: First, disqualifying the untrained or unsuitable applicant, and second, indicating where a welder lacks in thoroughness with reference to a range of welding conditions which can be predetermined.

2. The prescribed welding designs provided ample reserve strength to safely withstand the assumed working loads of each specimen.

3. The design procedure determining the welding about the brackets of Fig. 1, while admittedly being irrational in several respects, provided a simple and economical means for limiting the end or terminal stress to within conservative limits and it was observed that the estimated ultimate terminal stress at failure was in close agreement with the maximum strength of the weld metal produced for these tests.

"High Tensile Atomic Hydrogen Arc Welds in Alloy Steels"

By **FREDERICK RAY**

✦ This paper was presented at the Annual Meeting of the American Welding Society, April, 1931, by Frederick Ray, Consulting Engineer of the Croll-Reynolds Engineering Co.

IN the development of the Flexo Disc Expansion Joint, illustrated in Figs. 1 and 2, which as seen consists of a steel bellows constructed of corrugated steel discs welded together at their inner and outer peripheries and provided with suitable pipe connections, it was necessary to obtain a weld of the same physical characteristics as the plates in order to utilize the strength and elasticity of the plates to the full extent.

Expansion joints are commonly used in high pressure steam lines and are required to stand high internal pressure in addition to the stresses set up by the expansion and contraction of the pipe line. The internal pressure sets up bending stresses in the discs which approximately vary inversely as the square of the thickness, while the movement of the discs sets up stresses which vary directly as the cube of the thickness. As a result, increasing the thickness to reduce the pressure stresses either increases the movement stresses or reduces the amount of movement per disc. The actual deflection of such discs and the pressure stresses set up in the construction shown under usual working conditions met in practice are such that a practical commercial joint cannot be constructed from material of low elastic limit, such, for instance, as mild steel.

The use of steel of high elastic limit, on the other hand, requires that the welds should likewise have a high elastic limit, since the stress in the welds is as great as at any point in the plates. Furthermore, it is not possible to build up a weld of large cross section as compared to the thickness of the plates, and by this method make use of welds of reduced unit strength because there is always a section where the plate joins the weld which will extend through the welded material and which will be of no greater thickness than the plate without regard to the cross section of the weld itself.

Various alloy steels of great strength and high elastic limit are available at the present time. All such steel must be heat treated in order to fully utilize their properties, and while this heat treatment greatly increases the strength and the elastic limit of the discs, which strength and elastic limit must be equalled by the material of the weld, it permits at the same time a suitable heat treatment of the weld, which has been found to improve the weld as much as the plates themselves.

In Figs. 1 and 2 it is seen that the discs are so corrugated that they nest together at their outer and inner peripheries, so that they tightly contact on their faces at these two points for a radial distance of an eighth of an inch or so.

In welding, which is done by the Atomic Hydrogen Process, the arc is directed radially upon the edges of the two contacting plates, so that the edges are melted down and flow together to form a small bulb of melted metal as shown in Fig. 3. This results in the weld being formed of the melted metal of the plates themselves without the addition of metal either deposited by an arc or added by means of a wire or rod. To perform the welding operation with a minimum of manual labor, the plates are first mounted in pairs with their inner edges contacting in a welding jig which is arranged to rotate them at a uniform speed and the arc is directed manually upon the edges of the plates, melting them together as previously stated.

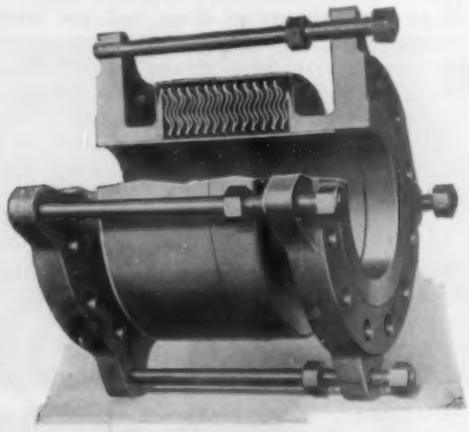


Fig. 1—Welded Expansion Joint

To build up the bellows, the desired number of pairs of plates are assembled in this jig and similarly welded together at their outer edges. Fig. 4 shows a number of pairs of plates assembled together in this jig with the welding electrodes being held in place by the operator in a position to weld the outer edges of the disc. Fig. 5 is a similar view with the arc in operation.

In practice it has been found that these welds can be made at a speed of about one foot per minute on plates approximately 1/16 in. in thickness. The steel which is being used at the present is a 3½ per cent nickel

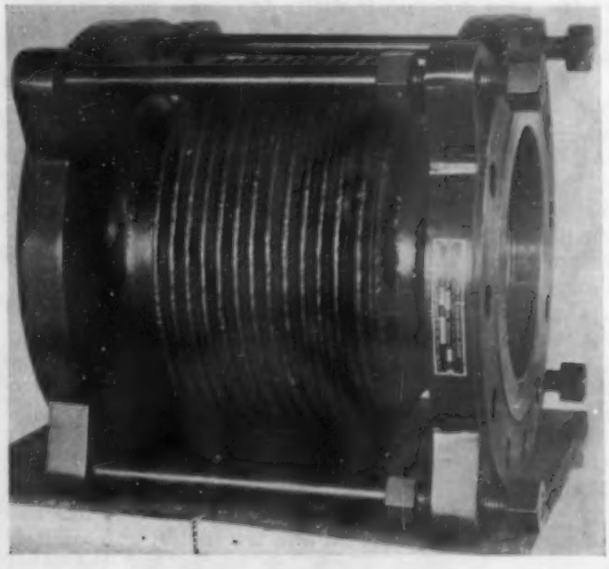


Fig. 2—Welded Expansion Joint

steel, S.A.E. Specification No. 2335. This steel has a carbon content of from 0.30 per cent to 0.40 per cent with manganese from 0.50 per cent to 0.80 per cent and nickel from 3.25 per cent to 3.75 per cent.

Referring to Fig. 2, it is seen that the corrugated discs are welded at each end to relatively thick plain discs, which in turn are welded to the pipe flanges. These plain discs are of the same material and are beveled down so that their outer edges are of the same thickness as the corrugated discs and are welded to these discs at the same time that the outer edges of the corrugated discs are welded together. These thicker discs furnish a weld of high unit strength at their outer peripheries and one of low unit strength at their inner peripheries where they are welded to the mild steel pipe connections by an ordinary arc weld, the total strength being at least as great at the inner weld. After welding, the whole elastic element with its end plates, but without pipe connections, is heat treated, this treatment consisting of heating to a temperature of 1550 deg. F. for a period of about one hour, then quenching in oil and reheating or tempering at a temperature of from 650 deg. F. to 750 deg. F., depending upon the characteristics desired. With

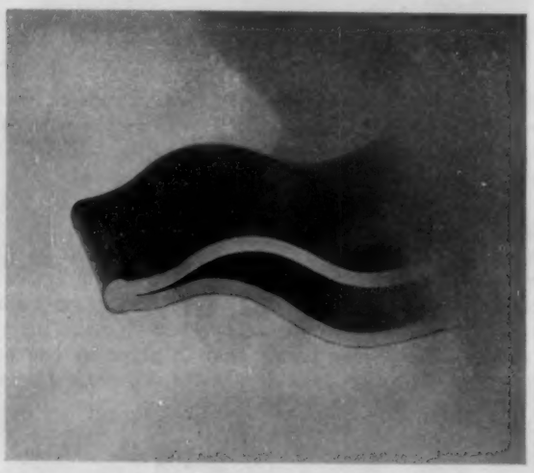


Fig. 3—Edges Welded Together

such a heat treatment, it has been found that the metal of the weld has substantially the same physical properties as the metal of the plates as far as it has been possible to determine.

Under the microscope, the metal of the original plate has a very fine grain structure, as is seen in Fig. 6, which was taken at some distance from the weld, where the structure was not affected in any way by the heat of the weld. Before heat treatment it is very easy to distinguish the metal of the weld from the metal of the plate when the metal is polished, even with the naked eye, and the difference in grain structure is clearly shown under the microscope.

Fig. 7 shows a view taken at the junction between the weld and the plates, the metal of the weld showing a coarser grain than the metal of the plate, although the metal of the plate at this point has been considerably affected by the temperature from the weld.

Fig. 8 shows a section which has been subjected to the heat treatment indicated above, the view being taken at the junction of the weld and the two plates, and it is seen that the grain structure is very fine and the same in both the weld and the plates, so that it is impossible to detect where one begins and the other ends.

It is quite impossible to determine the stress in the actual welds of the expansion joint by subjecting the joint to internal pressure or by subjecting it to axial load, since the determination of these stresses would depend upon calculations which are quite beyond the ordinary methods pursued in mechanics of materials.

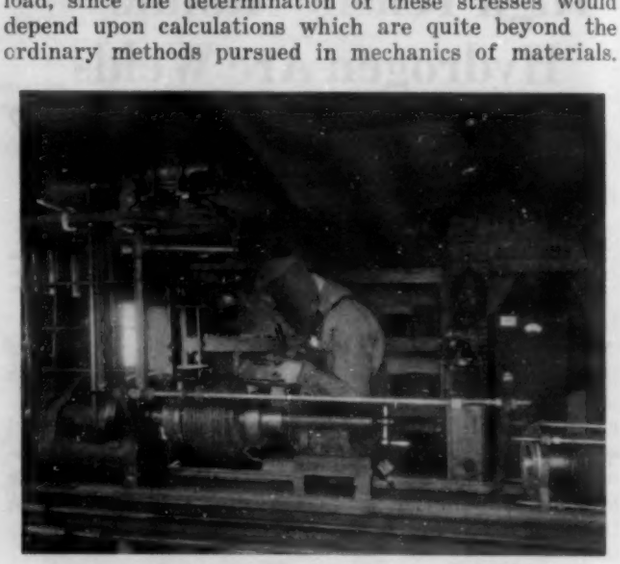


Fig. 4—Plates Assembled in Jig Ready for Welding

Consequently, to obtain actual tests on welds of this type, it has been necessary to make special samples by butt welding plates together and subjecting such samples to the usual tests.

As the only testing apparatus which has been available for this work consisted of a small compression machine developed for a special line of investigation and capable of exerting a pressure of but a few thousand pounds, it was only possible to test samples of small cross section. A great many tests of such butt welded samples have been made by testing the sample as a beam resting upon supports with the weld in the middle and the load applied at that point and observing the load and the deflection of the beam. By plotting the stress strain curve a reasonably accurate determination of the yield point can be obtained, but the breaking load cannot be found, as the beam takes too great deflection before breaking. Without exception, the yield point of such a beam with a weld extending crosswise at its middle point has been found to be the same as the yield point of such a beam made from the plate itself without a weld.

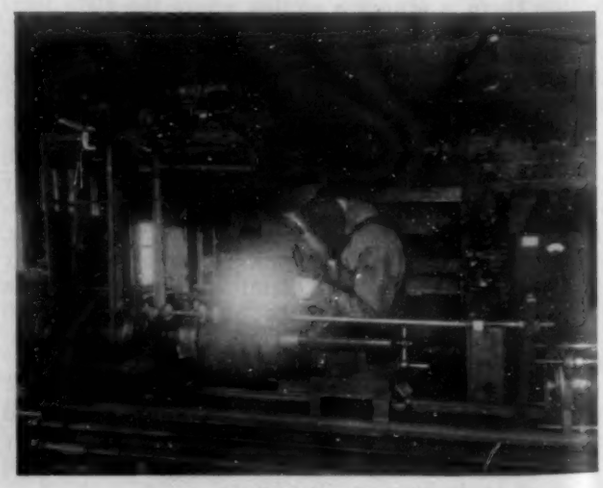


Fig. 5—The Welding Operation

The present tests, however, which are here referred to, have been made by subjecting small test pieces to tensile stress, these test pieces being shown in Figs. 9 and 10, these being all the test pieces of this type so far made of 3½ per cent nickel steel. No other tests whatever of this nature have been made, so that these results are not specially selected ones.

Test piece No. 1 was made of the plate without a weld. It was heated at 1550 deg. F. for one hour, hardened in oil and tempered at 650 deg. F. The cross section was 0.202 by 0.0665 or 0.0134 sq. in. The first observed flow of the metal was at a load of 2265 lb., which corresponds to a yield point of 169,200 lb. per sq. in. The test-piece broke at a load of 2520 lb. or 188,200 lb. per sq. in. ultimate strength.

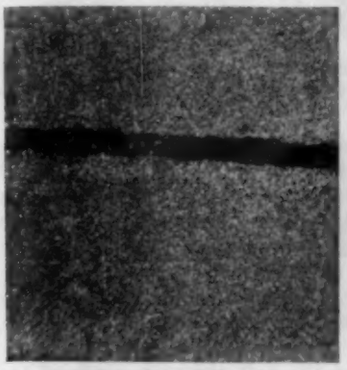


Fig. 6—Original Plate

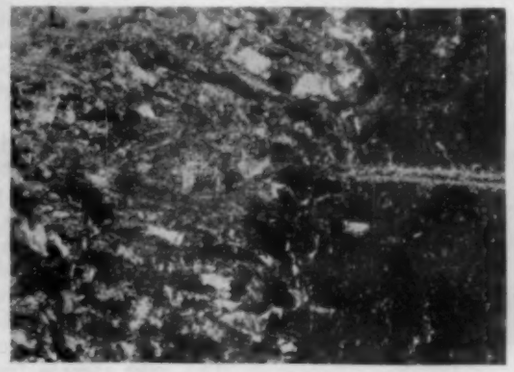
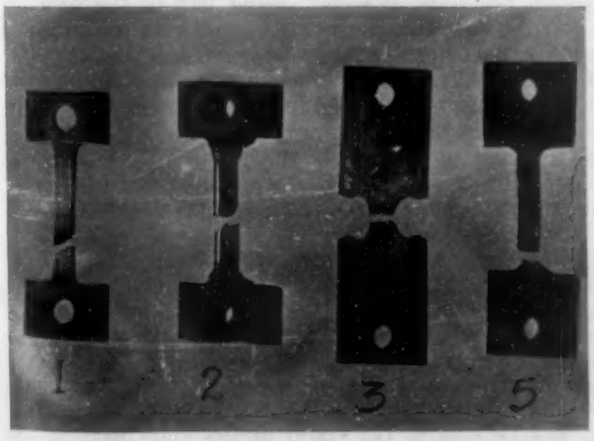
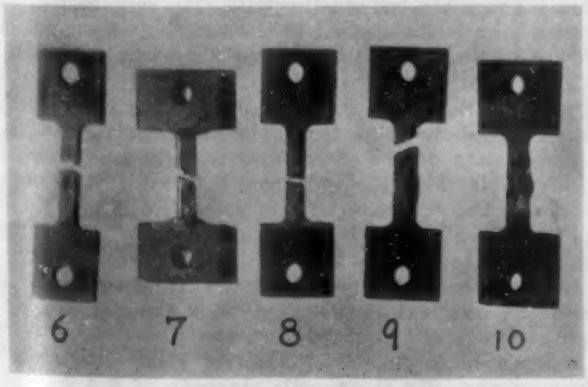


Fig. 7—Weld Junction Before Heat Treatment

Fig. 8—Junction After Heat Treatment

Test piece No. 2 was made from ¼-in. plates of the same material, which were butt welded together so as to give a considerable body of melted metal in the weld. The weld runs lengthwise of this test piece which has been turned down to a diameter of 0.141 in. so that all the metal within this cylindrical portion was the melted metal of the weld. It was heated to 1550 deg. F. for one hour, hardened in oil from that temperature and tempered at 650 deg. F. The first flow of metal was at 2220 lb. load, which corresponds to a yield point of 142,500 lb. per sq. in. It broke at a load of 2300 lb., which corresponds to an ultimate stress of 147,500 lb. per sq. in. An examination of the break showed that there was a small blowhole on one side and apparently a flaw in the weld which occupied a considerable portion of the area.





Figs. 9 and 10—Test Specimens

Test piece No. 3 was made from plates which were butt welded together, the sample being cut so that the weld itself extended crosswise across the narrowest portion of the test piece. It was impossible to detect the yield point with such a test piece, but it broke at a load of 2540 lb., which corresponds to a stress of 185,300 lb. per sq. in. The section at the narrowest point being 0.217 by 0.0632, which equals 0.0137 sq. in. This test piece was heated to 1550 deg. F. for one hour, hardened in oil from that temperature and tempered at 650 deg. F.

The break was not granular in appearance, but is smooth and amorphous, which is characteristic of the broken surfaces in all of these heat treated test pieces. The break seems to occur by shearing along the 45 deg. diagonal rather than by direct tensile strain. This likewise is more or less characteristic of the breaks of all the heat treated samples.

Test piece No. 5 was cut from butt welded plates, the weld extending crosswise of the test piece at its middle portion. The test piece was machined down so as to be of uniform cross section of the metal of the weld equal to the cross section of the metal of the plate. This test piece was not heat treated, but was in its original condition as welded. The cross-section was 0.0685 by 0.1575, equal to 0.0108 sq. in. The first observed flow was at a load of 900 lb. or a stress of 83,300 lb. and the test piece broke at a load of 1080 lb. or a stress of 100,000 lb. per sq. in. As seen from the photograph, the break occurred near one end of the reduced section quite some distance from the weld.

Test piece No. 6 was made from butt welded plates, the weld being left in its original condition, somewhat thicker than the plate itself. This test piece was heated to 1550 deg. F. and held at this temperature for something over one-half hour. It was hardened in oil from this temperature and tempered at 752 deg. F. The cross section of the test piece was 0.212 by 0.067

in., which equals 0.0142 sq. in. The yield point was not observed, but the test piece broke at a load of 2000 lb. or a stress of 141,000 lb. per sq. in. There was a blowhole of about 1/32 in. in diameter at one side of the break which caused the break to occur at this point just to one side of the weld. The appearance of the break was very fine and in all probability the strength of the metal itself was considerably greater than indicated above.

Test piece No. 7 was made from another portion of the ¼-in. nickel steel plates from which test piece No. 2 was taken. In this instance also the weld runs lengthwise of the test piece, which is turned down to a diameter of 0.1545 so that all the metal within this cylindrical portion is melted metal of the weld itself. It was heated to 1550 deg. F. for about three-quarters of an hour, hardened in oil at this temperature and tempered at 752 deg. F. The area of the cylindrical portion of the test piece is 0.01873 sq. in. Flow was first observed at 2820 lb. load or a stress of 150,500 lb. It broke at a load of 3000 lb. or a stress of 160,000 lb. per sq. in.

Fig. 11—Welds Subjected to Bending

Test piece No. 8 was made from butt welded plates and was heated to 1550 deg. F. for over one-half hour, hardened in oil from this temperature and tempered at 752 deg. F. The section is 0.192 by 0.054, which is equal to 0.01037 sq. in. The weld extends transversely of the test piece at its middle portion and was machined down so as to have the same cross section as the metal of the plate itself. This test piece broke at a load of 1600 lb. or 154,500 lb. per sq. in. There was a slight depression due to the welding operation or lack of alignment of the plates which was not quite cleaned up in machining down the weld and the break occurred at this point.

Test piece No. 9 was made from butt welded plates and was heated to 1550 deg. F. for over one-half hour, hardened in oil from this temperature and tempered at 752 deg. F. The cross section is 0.2135 by 0.065, which equals 0.0139 sq. in. The weld extends transversely of the test piece near its middle portion and was not machined down, but left in its original condition, which was somewhat greater in thickness than the plate itself. The test piece broke at a load of 2310 lb. or 167,500 lb. per sq. in. This break, as seen from the photograph, occurred in the original metal of the plate at some distance from the weld.

Test piece No. 10 was made from butt welded plates and was heated to a temperature of 1550 deg. F. for one-half hour, hardened in oil from this temperature and tempered at 752 deg. F. The cross section is 0.156 by 0.086, which equals 0.0134 sq. in. The weld extends transversely of the test piece near its middle and was not machined down, but left in its original condition. This test piece was subjected to a maximum load of 2200 lb., under which condition the metal was flowing rapidly and necking down near the upper end of the test piece and would have broken at this point if the load had been continued. The load, however, was removed before breaking. The maximum load corresponds to a stress of 164,000 lb. to the square inch. As is seen, the break would not have occurred in the weld.

A number of test pieces which have been subjected to a bending test are shown in Fig. 11. Such a test gives a rough idea as to the relative ductility of the material. All of these pieces were clamped in a vice and bent over one of the sharp edges of the jaws by hammering, which subjected them to a pretty severe shock.

The sample at the left of the photograph is a piece of steel 0.065 in. in thickness which has a butt weld running transversely that has been machined down to the same thickness as the plate. This was clamped in the vise so that the edge of the jaw came directly at the center of the weld and was bent until it began to crack along the convex side and would have broken with but very slight additional movement. This piece bent through an angle of approximately 49 deg.

The next sample from the left shows a piece of the original plate of the same thickness without a weld and was bent in the same manner, and bent through exactly the same angle when the development of cracks on the convex side showed the beginning of the break. The similar behavior of the two samples is a rough indication at least that the ductility of the weld is substantially the same as that of the plate, both having been subjected to the same heat treatment.

The third sample from the left represents a similar plate which has been butt welded and similarly heat treated, the weld, however, being left in the original state somewhat thicker than the plate. It was clamped in the vise as close to the weld as possible and bent until the metal began to crack along the convex side. This bent through a slightly greater angle than the other two samples, although the plate is 0.083 in. thick. The interesting point is that the weld itself was not affected in the least by the severe hammering to which the sample was subjected, the failure being in the metal of the plate next to the weld.

The sample at the right of the picture is a similar piece which has been welded transversely, but which was annealed. The weld in this case was left in its original state somewhat thicker than the plate and the sample was clamped in the vise as close to the weld as was possible. This sample bent about 80 deg. about the edge of the jaw of the vise, with cracking along the convex side in the metal of the plate next to the weld. The plate beyond the weld also bent under the force of the blows applied to the end, but the metal in the weld being slightly heavier did not bend.

These tests clearly indicate the absence of any greater brittleness in the weld than in the plate itself, both having been subjected to the same heat treatment.

The results of the above tensile tests are collected in the table, Fig. 12, and from this table it is seen that with the exception of test pieces No. 2 and No. 6 the breaking strength was substantially the same for all the test pieces tempered at the same temperature, and that the strength of the metal of the weld itself was as great as the strength of the metal of the plate.

Bullen's book on "Steel and Its Heat Treatment" gives on page 258 the tensile strength of S.A.E. 2330 steel tempered at different temperatures and similarly

on page 260 gives the tensile strength of S.A.E. 2340 steel.

Taking the average of these two charts as representing S.A.E. 2335 steel, such steel tempered at 650 deg. F. would have an ultimate strength of 188,000 lb. per sq. in. and tempered at 752 deg. F. would have an ultimate strength of 165,000 lb. per sq. in.

	Tempering Temperature, Deg. F.	Yield Point, Lb. per Sq. In.	Breaking Stress, Lb. per Sq. In.	Location of Break
1.	650	169,200	188,200	Original plate
2.	650	142,500	147,500	Metal of weld blow hole
3.	650		185,300	Metal of weld
*5.		83,300	100,000	Metal of plate
6.	752		141,000	Side of weld blow hole
7.	752	150,500	160,000	Metal of weld
8.	752		154,500	Side of weld, slight depression in surface
9.	752		166,500	Metal of plate
10.	752		164,000	Metal of plate

*All pieces except No. 5 hardened in oil from 1550 deg. F.

FIGURE 12

Referring to the table of Fig. 12 the results obtained in these tests check almost exactly with Bullen's figures.

While the test pieces used in conducting these tests differ considerably from the accepted practice, the results obtained cannot in any way be attributed to the size of the sections used since, if anything the results from a small section will be affected relatively more by a slight imperfection in the weld than a larger section. As the welds are actually used they are subjected almost entirely to bending stresses transversely to their length under which conditions a small blowhole or flaw would have a very small percentage effect upon the strength of the weld as a whole. And as a matter of fact, the imperfections in the welds as commercially made are so slight that their effect upon the strength of the weld as a whole can be neglected.

The unit strength, therefore, of the welds can be taken identically the same as the unit strength of the original metal of the plate, so that in the construction of an expansion joint of the type illustrated it is simply necessary to make the cross sectional area of the welds at least equal to the cross sectional area of the plate to permit the plates to be subjected to movement and pressure stresses as near the elastic limit as would be permissible in a similar structure without welds.

Current Welding Literature

Airplane Manufacture—Welding. The Cause and Prevention of Heat Cracks in Aircraft Welding, H. S. George. Am. Soc. Mech. Engrs.—Advance Paper, for mtg. May 12-14, 1931.

All-Welded Hopper Car Has Greater Load Capacity. The Iron Age. (April 16, 1931), Vol. 127, No. 16, pp. 1279-1280.

Applications and Progress of the Air-Acetylene Torch. H. A. Morgan. Mechanical and Welding Engineer. (March 14, 1931), Vol. 5, No. 3, pp. 94-98.

Boiler Manufacture—Welding. New Technique in Welding is Result of Years of Scientific Research, K. B. Lydiard. Pit and Quarry (April 22, 1931), Vol. 22, No. 2, pp. 62-64.

Bronze Welding of Cast Iron Pipe, The. Welding. (April, 1931), Vol. 2, No. 4, pp. 235-237 and 241. Two recently completed water pipe jobs emphasize the advantage of this application.

Bronze Weldnig of Cast Iron, E. J. Raymond. Mechanical and Welding Engineer. (March 14, 1931), Vol. 5, No. 3, pp. 108-113.

Building Codes—Welding. Regulations for Structural Welding in Germany, I. Bondy. Iron Age. (April 2, 1931), Vol. 127, No. 14, pp. 1074-1079. Review of rules for erection of welded steel building with practical example illustrating different types of joints; table gives permissible unit stresses for both Germany and United States.

Buildings, Steel—Electric Welding. Arc Welding a New Method of Building Construction, B. M. Shimkin. West. Machy. World. (April, 1931), Vol. 22, No. 4, pp. 116-167. Buildings and structures that have been totally or partially welded; over 50 buildings have been or are being welded at present time; all-steel battle-deck floor.

Cast Iron Today, A. B. Everest. Machy. Market (Lond.), Nos. 1588 and 1589. (April 10, 1931), pp. 21-22, and (April 17), pp. 17-18.

Designing for Rapid Production of Spiral Welded Pipe. Leon Cammen. Machine Design. (April, 1931), Vol. 3, No. 4, pp. 45-47.

Electric Motors—Welding. Resistance Welding Improves Motor Frames, M. Thomson. Elec. Eng. (April, 1931), Vol. 50, No. 4, pp. 273-275.

Electric Welding, Arc. Automatic Arc-Welding, G. Erenyi. AEG Progress. (March, 1931), Vol. 7, No. 3, pp. 59-63.

Electric Welding, Arc. Transforming Reactor Improves D-C. Arc Welding, S. R. Bergman. Elec. Eng. (April, 1931), Vol. 50, No. 4, pp. 283-285.

Electric Welding, Arc—Testing. Inspection Safeguards Quality, R. Kraus. Welding Engr. (April, 1931), Vol 16, No. 4, pp. 27-31.

Electric Welding, Resistance. Applications of Resistance Welding, M. L. Eckman. Welding Engineer. (April, 1931), Vol. 16, No. 4, pp. 38-40.

Electric Welding, Resistance. Resistance Welding Applicable to Jobbing and Repair As Well As To Production, M. L. Eckman. Iron Age. (April 30, 1931), Vol. 127, No. 18, pp. 1440-1443.

Electric Welding Electrodes. The Welding of Metals, Especially With Flux-Coated Electrodes, E. D. Lacy. Can. Machy. (April 2, 1931), Vol. 42, No. 7, pp. 42-44 and 46.

Electric Welding Machines. Modern Electric Welders. Elec. Rev. (March 20, 1931), Vol. 108, No. 2782, pp. 506-507.

Electrically Welded Crane, A. H. Collins. Mechanical and Welding Engineer. (March 14, 1931), Vol. 5, No. 3, pp. 91-92 and 121.

Fusion Welding Results As Analyzed by the Steel Foundryman. Research Group News. (April, 1931), Vol. 8, No. 1, pp. 375-389.

Gas Pipe Lines—Welding. Development and Results of Arc Welding of Gas Pipe Lines, H. C. Price. Oil and Gas Journal. (April 16, 1931), Vol. 29, No. 48, pp. 148 and 150.

Gas Welding and Cutting for Garage Profits. Welding (April, 1931), Vol. 2, No. 4, pp. 242-245. Crankcase, cylinder block and body repairs and the fabrication of trailers, dump bodies and fender wells open up a new field of profit.

Heating and Ventilation Systems—Oxyacetylene Welding. Oxy-Acetylene Welding, As Applied to Heating and Ventilating Engineers, E. B. Partington. Domestic Eng. (Lond.), Vol. 51, No. 4, pp. 77-79, April, 1931.

Industrial Plants—Construction. Arc Welding Used in Windowless Plant, C. M. Taylor. General Building Contractor. (April, 1931), Vol. 2, No. 4, p. 43. First windowless industrial plant in world under construction for Simonds Saw and Steel Co., in Fitchburg, Mass., features trusses fabricated by arc-welding process, and arc-welded steel deck roof; plant consists of one building 560 ft. long, 360 ft. wide; there are 136 trusses each 70 ft. long and 63 carrying trusses 40 ft. long.

Here's How It's Welded. Magazine published by The Industrial Publishing Company, Cleveland. February, 1931, issue contains; Welding Solves Difficult Problem in Skyscraper. A Review of Stresses in Welded Joints, by Alfred Jaeger. Spiral Fort Ramp is Welded Throughout. Judging the Quality of a Weld, by R. L. Ewen.

Installs All-Welded Steel Plate Tank for By-Product Storage Purposes. Steel. (April 23, 1931), Vol. 88, No. 17, p. 54.

Iron and Steel From the Point of View of the Welding Operator, J. Neill Greenwood. Mechanical and Welding Engineer. (March 14, 1931), Vol. 5, No. 3, pp. 78-81.

Items Affecting Welding Costs, W. L. Franklin. Welding. (April, 1931), Vol. 2, No. 4, pp. 232-234.

Machinery Exhibition—Birmingham, England. British Industries Fair. Sheet Metal Industries. (March, 1931), Vol. 4, No. 11, pp. 947-971. Exhibits of sheet-metal machinery and welding equipment exhibited at Fair which opened in Birmingham, Feb. 16, 1931.

Machinery Manufacture—Welding. Welded Construction Applied to Special Machinery, D. V. Waters. Product Eng. (April, 1931), Vol. 2, No. 4, pp. 167-170.

Monoferric Construction, made possible by Arc Welding and Oxy-Cutting, enables Metropolitan Gas Company to design economical structure. Mechanical and Welding Engineer. (March 14, 1931), Vol. 5, No. 3, pp. 114-119.

New Pipe Mills at McKeesport Works of National Tube Company, Sidney G. Koon. The Iron Age. (May 7 1931), Vol. 127, No. 19, pp. 1502-1507. Demand for large-diameter pipe for long distance pipe lines has been so heavy that the new electrically welded pipe department of the National Tube Co. has been operating both day and night.

Oxy-Acetylene Welding. The Welding of Alloys. Oxy-Acetylene Tips. (April, 1931), Vol. 10, No. 4, pp. 71-76.

Oxy-Acetylene Welding and Cutting, F. E. Rogers and F. J. Maeurer. Industry and Welding. (April, 1931), Vol. 2, No. 4, pp. 19 and 26-28.

Pipe Lines—Welding. Economies of Gas Welded Pipelines, E. Larson. Welding Engr. (April, 1931), Vol. 16, No. 4, pp. 33-36.

Pipe Lines—Welding. Magnetic Testing of Pipe Welds is New Inspection Method, H. R. Simons. Steel. (March 5, 1931), Vol. 88, No. 10, pp. 39-42. Portable magnetic testing machine developed by Ferrous Magnetic Corp., New York, for conducting field tests on pipe-line welds.

Pipe Lines—Welding. 1930 Piping Jobs Simplified by Welding, W. R. Wood. Heating and Piping Contractors Nat. Assn.—Off. Bul. (April, 1931), Vol. 38, No. 4, pp. 37-39. Advantages of welding as exemplified by Empire State and Cornell Medical Center installations.

Pipe, Steel—Oxyacetylene Cutting. Production Methods on Screen Casings, C. A. Handschin. West. Machy. World. (April, 1931), Vol. 22, No. 4, pp. 162-165. Machines for slotting oil-well tubing used at plant of Kobe, Inc., Los Angeles, Cal.

Power Plant Equipment—Electric Welding. Arc Welding in the Power Plant, W. H. Zorn. Power. (March 31, 1931), Vol. 73, No. 13, p. 528. Also in Mech. Eng. (April, 1931), Vol. 53, No. 4, p. 301.

Resistance Welding Applicable to Jobbing and Repair As Well As to Production, M. L. Eckman. The Iron Age. (April 30, 1931), Vol. 127, No. 8, pp. 1440-1443.

Rivets or Welds? Lee H. Miller. Steel. (May 7, 1931), Vol. 88, No. 19, pp. 48 and 50.

Rolling Mills—Billet Scarfing. Scarfing Process is Effective in Eliminating Defects, J. D. Knox. Steel. (March 19, 1931), Vol. 88, No. 12, pp. 36 and 38. Use of oxyacetylene scarfing torches for removing such defects as seams, scabs and scratches from surface of billets, slabs and other semi-finished shapes.

Shipbuilding—Electric Welding. Experiences with an Electrically-Welded Ship. Engineering. (April 3, 1931), Vol. 131, No. 3403, pp. 46-461. Fullagar, now known as Shean, was launched in 1930; vessel has several times been aground and on each occasion, later examination showed keel and bottom plating to have stood severe conditions without ill effect; after more than 11 years of service it has been impossible to trace any undue corrosion in welded structure; experiences form remarkable demonstration of possibilities of electric welding in ship construction and valuable tribute to methods and materials of Quasi-Arc Co.

Some Research Problems in Electric Arc Welding. R. R. Blackwood. Mech. and Welding Engineer. (March 14, 1931), Vol. 5, No. 3, pp. 82-85.

Spiral Welded Pipe. Power Plant Engineering. (April 15, 1931), Vol. 35, No. 8, p. 480.

Street Railroad Tracks—Welding. Welding Manganese Track Work, H. H. George. Traction Shop and Roadway. (March, 1931), Vol. 4, No. 3, pp. 77-80; see also Elec. Traction. (March, 1931), Vol. 27, No. 3, pp. 125-127.

Structural Arc Welding. A. F. Davis. Welding. (April, 1931), Vol. 2, No. 4, pp. 246-251.

Structural Steel Welding. A Consulting Engineer Looks at Structural Welding, G. D. Fish. Steel. (March 19, 1931), Vol. 88, No. 12, pp. 34-35 and 38. Effect of welding on design of structures; factors governing economy in joints; elimination of gusset plates.

Structural Steel Welding. Structural Welding for Profit. Eng. News-Rec. (April 30, 1931), Vol. 106, No. 18, pp. 737-738. Notes on proceedings of annual convention of American Welding Society; outlines of Dominion Bridge Co.'s welding philosophy and practice; structural steel welding committee reports; test program; welding research.

Structural Steel Welding—Germany. Welded Steel Buildings in Germany, O. Bondy. Welding Jl. (February, 1931), Vol. 28, No. 329, pp. 42-44.

Tests on Spot Welder. R. J. Wilson and P. L. Orr. Welding. (April, 1931), Vol 2, No. 4, pp. 238-241.

The Welded Portion of the Coal Bunkers at Yallourn, Victoria. D. E. Baldwin. Mech. and Welding Eng. (March 14, 1931), Vol. 5, No. 3, pp. 86-89.

The Welder. (April, 1931), Vol. 2, No. 14. Published by Murex Welding Processes, Ltd., London. Contains: Gas Engine Pistons Repaired by Welding. The Training of Welders Supplement; and others.

Ventilation Ducts—Welding. Welded Fabrication of Ductwork, W. Spraragen. Heat. and Vent. (March, 1931), Vol. 28, No. 3, pp. 54-57. Preparation of material in repetitive production work; types of joints; expansion and contraction; stack welding.

Waterwheels—Welding. Welding of Water Wheels. Nat. Elec. Light Assn.—Pub., No. 116. (April, 1931), 12 pp.

Welded Bridge in Western Australia. C. Curtayne. Mech. and Weld. Eng. (March 14, 1931), Vol. 5, No. 3, pp. 99 and 125.

Welded Continuous Trusses Utilized in Australian Highway Bridge. Engineering and Contracting. (April, 1931), Vol. 70, No. 4, pp. 97-98.

Welded Steel Pipe in Turbine Construction, Harold L. Alt. Power Plant Engng. (April 15, 1931), Vol. 35, No. 8, p. 451. Details of 82-in. steel pipe connecting elements of cross-compound turbine.

Welded Wind Connections on New 14-Story Boston Building. Engineering and Contracting. (April, 1931), Vol. 70, No. 4, p. 102.

Welding. Many Industries Represented by Students at Conference on Welding, F. L. Plummer. Cleveland Eng. (March 26, 1931), Vol. 23, No. 43, pp. 3-8 and 15-16.

Welding. Recent Progress in Welding. Engineering. (April 17, 1931), Vol. 131, No. 3405, p. 524.

Welding Machines. Flash Butt-Welding Machines for Mass-Production, N. A. Bolt. AEG Progress. (March, 1931), Vol. 7, No. 3, pp. 64-67.

Welding Machines. New Cross-Field Welding Converter, G. Erenyi. AEG Progress. (March, 1931), Vol. 7, No. 3, p. 63.

Welding of Structural Steel. J. E. Ferguson. Industry and Welding. (April, 1931), Vol. 2, No. 4, pp. 3-5 and 20-24.

Welding—United States. A. S. T. M. Regional Meeting at Pittsburgh. Eng. News Rec. (March 26, 1931), Vol. 106, No. 13, pp. 529-530. Review of some 11 papers on current problems of welding, with special emphasis on inspection and testing; welding processes and applications.

Welds—Butt Straps. The Strengthening of Welded Joints by Cross-Straps, E. Hoehn. Engineering. (April 17, 1931), Vol. 131, No. 3405, pp. 525-526.

Welds—Inspection. Inspection of Arc Welds, R. Kraus. Elec. Jl. (April, 1931), Vol. 28, No. 4, pp. 219-222. Several practices are open to weld inspector by which he can judge weld quality; observation of operators' technique, inspection of wells visually and with gages, and periodic tests of sample welds.

Welds—Stresses. Stresses in Large Fillet Welds, C. H. Jennings. Product Eng. (March, 1931), Vol. 2, No. 3, pp. 116-118.

X-Ray and Welded Structures, The. Herbert R. Isenburger. Welding. (April, 1931), Vol. 2, No. 4, pp. 229-231.

President's Report

(*Continued from page* 4)

regarding the subject is being made. Further, that it is planned to hold a meeting of this committee during the present annual meeting.

The committee appointed to confer with the A.S.M.E. Boiler Code Committee and Compressed Gas Manufacturers' Association on the proposed classification of unfired pressure vessels, has held a number of meetings, the first one of which was a joint meeting of the three bodies, the second a meeting only of the American Welding Society Committee, then several meetings with the Compressed Gas Manufacturers' Association, after which these two bodies being in accord have had two additional meetings with the A.S.M.E. Boiler Code Executive Committee. This work is progressing and is demanding a great deal of attention, and as a result of it, it is believed that when the new edition of the A.S.M.E. Boiler Code is presented to the public, the welding fraternity in general will benefit greatly by the activities of the Society's representatives and many of the restrictions that have heretofore been imposed by the Boiler Code will have been removed.

The Committee on the Welding Exhibit, World's Fair Centennial celebration, has been quite active, but as there apparently has been some change in the method of handling exhibits, both scientific and industrial, it has been impossible to make a final report. This matter will continue in the hands of the existing committee and will be reported upon from time to time to your Executive Committee.

The secretary of the Committee on Standard Specifications for the Qualification of Welders reports that two meetings have been held and that another will be held during the week of April 20, 1931, at which time it is felt that as a result of a final discussion of the report, it will then be in condition to submit to the Executive Committee.

The Manufacturers' Committee has made a very comprehensive and lengthy report covering the question of whether the Society should foster expositions at each fall meeting or at every second fall meeting. This matter will be presented for discussion at the meeting of your Board of Directors, Thursday, April 23.

AMERICAN BUREAU OF WELDING—The activities of the bureau during the past year has been largely a continuation of the work started in previous years. A number of creditable accomplishments, however, can be recorded both in published reports and in work under way.

Fundamental Research Committee

The activities of this committee have been varied in nature and unusually successful. An outstanding feature was an inspection trip participated in by fifteen university professors.

A meeting was held in Boston on Wednesday, March 25, at which were present professors from M.I.T. and Harvard interested in this work, and also representatives from industry and the local Boston Section of the A.W.S. A plan was proposed by the professors present, namely, that the work in this vicinity be coordinated; that is, each of the professors undertake the solution of a portion of a single problem. This would involve a community interest and stimulate progress.

A number of published reports have resulted from the efforts of this committee during the past year. These were published in THE JOURNAL of the A.W.S. and include the following: "Calorimetric Study of the Arc," February, 1930, issue; "Cathode Energy of the Iron Arc," March, 1930, issue; "Examination of Welds by the X-Ray Diffraction Method," September, 1930, issue; "Notes on the Use of Gamma Rays for Examining Welds," September, 1930, issue; "A Study of Welded Metals Under Fatigue Tests," October, 1930, issue.

Structural Steel Welding

New Chairman. The committee reports with a great deal of sorrow the death of its chairman, Mr. James H. Edwards, on August 14, 1930. Mr. L. S. Moisseiff, consulting engineer, was selected by the American Bureau of Welding to succeed Mr. Edwards as chairman. In order to provide continuity of the work, Mr. H. M. Priest, formerly assistant to Mr. Edwards, was selected as vice-chairman.

Progress in Preparing and Testing of Specimens. The total number of specimens welded and tested are 1395. This is a total of 83 per cent of the entire number of specimens originally planned by the committee. Thirty-nine fabricating shops participated in the preparation of the specimens and 24 testing laboratories in the testing. The last laboratory report was received March 4, 1931, completing all the information on the specimens. At the present time, the fabrication and test data have been tabulated, arranged and partly analyzed. An outline of the report has been prepared and portions of it are now being drafted. It is expected that the report will be ready for submission to the committee by June for their criticism and suggestions.

Standard Tests for Welds

In June, 1921, the American Bureau of Welding issued Bulletin No. 1, entitled "Standard Tests for Welds." Experience and the advancement of the art since that time have shown a need for revision of these standards. A suggested revision has been prepared by the Committee on Standard Tests of the American Bureau of Welding in which only three standard tests are proposed, namely, tension, bending and shear. Impact tests and fatigue tests are desirable for complete information in regard to the mechanical properties of a weld, but it is doubtful if suitable technique for these tests has been developed to the point where standard procedures can be proposed.

In order to crystallize opinion and obtain the suggestions and experience of the entire membership of the Society, a symposium was arranged in connection with the fall meeting of the Society held in Chicago last September. The symposium consisted of a presentation of a suggested revision of the A.B.W. Bulletin No. 1, and prepared discussion on tensile, bend, shear and fatigue tests of joints. These papers were published in the September and October, 1930, issues of THE JOURNAL of the A.W.S.

Pressure Vessels

The activities of this committee during the past year have been confined largely to an investigation of light gage tanks manufactured by the resistance method producing a continuous butt weld and special forms of head construction for light gage tanks. A series of tests and examinations were made at Lehigh University and the results of these tests and the recommendations of the committee are published in the February, 1931, issue of THE JOURNAL of the A.W.S. The resulting actions taken by the Boiler Code Committee are reported in the March, 1931, issue of THE JOURNAL of the A.W.S.

Welding Wire

Consideration has been given during the past year to the extension of the present specifications of the committee to include requirements for physical tests made with the wires in addition to the chemical analyses given in the various classifications. It is proposed to add specifications for patented and other wires which cannot be covered by chemical analysis. The requirements for these classifications will depend almost entirely on the physical properties of the welds produced by these wires.

Rail Joints

The efforts of the committee during the past year have been confined very largely to finishing up its program of investigation and in publishing a seventh progress report. The material for this report is in preparation and it is expected that it will be published within another month. The committee is also considering the feasibility of a final report which will summarize the recommendations of the committee.

REPRESENTATION IN OTHER ORGANIZATIONS—Your representatives in other organizations have been active during the past year and have participated in meetings and assisted in the preparation of specifications in their several capacities.

A.S.M.E. Boiler Code Committee, covered in the earlier part of this report.

A.S.T.M.—The report from the representative covering the activities of the Sub-Committee XXI—Committee, A-1—A.S.T.M., reports that a meeting was held on Jan. 15 in Philadelphia, at which time consideration was given to specifications for steel of fire box and flange quality, also that the recommendations of Jan. 20, 1930, were reviewed and affirmed with respect to steel for fusion welding with certain exceptions and a new specification covering open-hearth iron was added to the list.

Initial steps were taken to consider specifications for welding wire, and five representatives of the American Welding Society have been added to the sub-committee to collaborate in the work.

The chairman of the committee prepared a paper for presentation at a welding symposium held in Pittsburgh in March. This paper was presented for review and suggestions.

A special meeting was held on Feb. 20, 1931, attended by the chairman and the Pacific Coast members of the sub-commit-

tee. This group covered specifications A-78-30 and A-89-30 as well as chemical properties, physical properties, etc.

A meeting held in Pittsburgh on March 19, 1931, was productive of very constructive motions and recommendations. It is recommended that those to whom the work of this committee is of particular importance, avail themselves of the opportunity to consider the report in full and pass on to the Society through its secretary such opinions and data as may be pertinent.

A.S.T.M.—Your representative on Committee B-5, Sub. I, A.S.T.M., reports by furnishing Minutes of Meeting held in New York on Feb. 18, 1931. This report consists of five pages of data. Space will not permit of including the details in this document, but like all reports of your representatives to other organizations, it will be made available to you through publication.

A.S.A.—Your representative on the A.S.A. Sectional Committee on electrical definitions has reported as follows:

A Sectional Committee has been organized under American Standards Association procedure with the American Institute of Electrical Engineers as sponsor. The project is a comprehensive one of preparing a glossary of electrical terms with their definitions for the entire electrical field.

The work is being carried on by subcommittees, each having in hand one subdivision of the electrical industry. The Sub-Committee on Welding is made up of men who have participated in and are thoroughly familiar with the American Welding Society work in this direction through its Committee on Nomenclature, Definitions and Symbols, with the A.W.S. representative on the Sectional Committee as chairman.

The Sub-Committee has reported to the Sectional Committee a proposed list of terms (a total of 152) on welding and cutting to be included in the glossary. Definitions for these terms will be formally submitted by the Sub-Committee just as soon as those proposed definitions have been reviewed by the A.W.S. Committee recently appointed to revise the A.W.S. standard definitions for these terms.

In other words, it is proposed that the definitions on welding and cutting which will go in this glossary shall be in exact agreement with those standardized by the American Welding Society.

A.S.A.—Your representative on the A.S.A. Sectional Committee on Electric Welding Apparatus has supplied the following report:

A Sectional Committee on Electric Welding Apparatus has been organized under A.S.A. procedure and the sponsorship of the American Institute of Electrical Engineers and the National Electrical Manufacturers' Association, with the A.W.S. representative thereon as chairman. Two projects have been assigned to the committee, namely, electric welding apparatus and resistance welding apparatus, the scope for each being as follows: "The Formulation of Standards for Electric Welding Apparatus, including definitions of terms, classification, rating, heating, efficiency, testing methods, dielectric test, standard values of current and voltage, and nameplate data."

The work of the Committee will be based on the present standards of the American Institute of Electrical Engineers, namely, No. 35 on "Electric Welding Apparatus" and No. 39 on "Resistance Welding Apparatus." Criticisms of these standards are now being collected from the industry and it is expected that the Committee will be in position to make its report within the next few months.

A.S.M.E.—American Welding Society representative on the A.S.M.E. Committee on Pressure Piping reports that there was a meeting of Sub-Committee No. 8 on Dec. 1, 1930, covering the subject of "Fabrication Details," and a meeting of the General Committee on Dec. 3, 1930, at the Engineers' Societies' Building, New York City.

A specification covering the fabrication of hangers, supports, anchors, sway bracings and vibration dampeners was gone over and the general comments which had been received were discussed and certain changes made in the tentative specifications submitted. This is to be redrafted along the lines approved by the committee and circularized through its membership.

The sub-group on "Joints, Other Than Welded Joints" submitted a detailed report which is to be condensed and passed along to the piping sub-committees for their recommendations as to the type of joints to be used, after which the fabrication committee will prepare details as to the design.

The recommended welding code, as prepared by your committee and as submitted to the A.S.M.E. Committee, was revamped in accordance with suggestions which resulted in its being circularized through the membership. This tentative revision was discussed and a number of additional suggestions were made at the meeting of the general committee on Dec. 3. The conclusion arrived at regarding the welding part of the Code was that the subgroup on welding, of Sub-committee No. 8, on fabrication details, was to meet with your committee to go over the comments received and changes suggested, after which the welding portion of the code will be rewritten and passed out to the membership for further comments.

A.S.M.E.—Conference Committee on Welding with Boiler Code Committee.

This committee cooperated with the A.S.M.E. Boiler Code Committee during the past year and reported upon nine problems pertaining to the application of welding to the fabrication of boilers and pressure vessels. These have been handled as problems XIV to XXII and have in all cases been considered with great care. These actions when completed were presented to the American Welding Society's Executive Committee for approval, after which they were transmitted to the A.S.M.E. Boiler Code Committee.

N. B. of B. and P. V. I.—The American Welding Society's representative on the Executive Committee of the National Board of Boiler and Pressure Vessel Inspectors attended the Eighth Annual Meeting of that Board in Chattanooga, Tenn., June 17 to 19, 1930, also three other meetings of the Executive Committee, at which plans for the Annual Convention were considered and action taken on technical questions that have been submitted to the organization. This report will appear in full at a later date.

A.S.S.T.—Recommended Practice Committee.

Your representative on the Recommended Practice Committee of the A.S.S.T. reports that he is serving in two capacities, one as a member of the A.S.S.T., the other as a representative of the American Welding Society, and that during the past year he has attended three meetings of the Committee, one in Cleveland, one in New York and one in Pittsburgh, and that with one exception no questions were brought up that pertained to the interests of the American Welding Society.

Space and time will not permit of the presentation to you now of all the details of the activities of your various other committees, sectional representatives, officers and general office staff. In fact, this report has already grown to a size that could be easily criticized, and yet were I to endeavor to give all of the details to which you may feel you are entitled, and to which you actually are entitled, the report would grow into book size and its reading would take up probably the whole of the first day of this annual meeting. I must, therefore, request that you bear with me for including the number of details that are herein included, and ask your indulgence for not having compiled a book, parts of which would be interesting to some, parts to others and the total to but a few.

In conclusion, I want to thank you in the name of the Society for the support that it has had from its membership during this year that I have served you as president, and I trust that even though this unfortunate season of depression remains with us for a short time longer, that there will be no falling off in the interest or membership of our growing organization. I believe that we all realize that in periods such as we are now passing through, that great benefits are derived from investigational research and development activities such as membership in the American Welding Society makes possible, but these possibilities cannot materialize unless wholeheartedly supported by each and every member. The last thought that I want to leave in your minds is in connection with the splendid work performed by your Executive Committee, I wish to point out to those of you who are not acquainted with the fact, that the men who form the Executive Committee meet regularly on the first Tuesday of every month and spend a full half-day, and sometimes a little more, giving to the Society the benefit of their knowledge and experience as applied to the vast number of subjects and questions that arise during the monthly periods between meetings. Moreover, it is, as a result of this untiring effort on the part of your Executive Committee that your president is able to come before you each year at the annual meeting and report progress of the Society and an ever-increasing interest in its growth and activities.

Respectfully submitted,

E. A. DOYLE,
President.

Annual Meeting

Another successful annual meeting of the Society was held April 22 to 24 in New York. There was a registered attendance of about 250.

The meeting opened with a short business session, report of Tellers' Committee and election of officers and the report of the president. There followed five technical sessions at which were presented thirteen important technical papers on various subjects, including shipbuilding, structural steel, research, pressure vessels, technique of welding, piping, thermit welding and the welding of non-ferrous metals. The papers for the most part were discussed in considerable detail and many interesting points were brought out. A special feature of the meeting was a joint meeting with the Pressure Piping Code Committee of the American Standards Association at which a tentative draft of the proposed Section of the Code dealing with Welding of Pressure Piping was presented and discussed. As a result of this meeting, the proposed code will be revised.

The Board meeting was well attended, as was also the annual dinner.

The Samuel Wylie Miller Memorial Medal for 1930 was presented at the dinner to E. H. Ewertz, past president of the Society. Complete details concerning this award will be given in the next issue of the JOURNAL.

At the annual meeting of the American Bureau of Welding, held Friday afternoon, the following officers were elected: Director, C. A. Adams; first vice-director, H. M. Hobart; second vice-director, J. H. Critchett; secretary, W. Spraragen. Reports of progress were presented by the various committees of the Bureau. A summary of this progress is given in the president's annual report.

There was a meeting of the Structural Steel Welding Committee which

was well attended. The work of the committee is rapidly approaching completion. A summary of the methods used by the committee in tabulating the data was illustrated. General conclusions were set forth. The aims of the committee are to:

1. Obtain reliable information upon which safe unit working stresses in the design of welded structures could be based.
2. Confirm or qualify previous results by the use of a large number of specimens, and a more uniform system of testing.
3. Supplement the scope of previous data by tests on additional forms of joints.
4. Determine what degree of uniformity in commercial welding may be expected.

The inspection trip arranged in conjunction with the Annual Meeting of the Society was held on Saturday, April 25, and included observation of the largest all-welded piping system ever installed in a building.

A comparatively small but highly representative party of over 50 members and guests assembled at the New York Hospital and Cornell Medical Center at Seventieth Street and East River and were escorted through the three lower floors of the building, where they were able to observe at close range the greater portion of over 50,000 ft. of all-welded piping from 2½ in. to 24 in. in diameter (including all-welded fittings) used for various purposes at pressures up to 350 lb.

Visitors were very much impressed with the fine workmanship and skillful layout as well as the substantial savings and obvious durability of the entire installation. It was regretted that the threatening weather and the comparative inaccessibility of the Medical Center prevented a larger number from attending.

Considerable credit is due to Charles Kandel, general manager of the Craftsweld Equipment Corporation, for arranging the details of this inspection trip.

Obituary

D. H. Deyoe

Daniel H. Deyoe, of the Industrial Engineering Department of the General Electric Company at Schenectady, died on April 11 at the Ellis Hospital, Schenectady, after an illness of six weeks.

D. H. Deyoe

Mr. Deyoe was born at Beacon Hill, Saratoga County, N. Y., Dec. 28, 1875, and graduated from Union College in 1898. He spent his summer vacations in 1897 and 1898 working at the Schenectady Works, and after graduating from college was employed in the commutator department, doing assembly work. In June, 1900, he joined the testing department, and was subsequently transferred to the (then) switchboard department, and from there to the power and mining engineering department, now the industrial engineering department.

He was an outstanding figure in the arc welding field, and was a director and member of the executive committee of the American Welding Society. He had a large circle of friends and acquaintances both within and outside the G. E. organization.

He was chairman of the American Welding Society's Committee on Welding Codes for Pressure Piping, which commitee is working in close cooperation with the American Standards Association's committee on the same subject.

Wilson Erwin Symons

Wilson Erwin Symons, charter member of the American Welding Society and its past treasurer, died on May 1, 1931. Mr. Symons was born on Dec. 18, 1858. He was a well-known railroad engineer and expert. He served in various capacities with the Wisconsin Central Railway Company and then with the Atchison, Topeka & Santa Fe Railway Co. In connection with this latter organization he rose from the ranks of locomotive engineer to operating engineer of their Chicago plant, division foreman and then master mechanic. He was also master mechanic with the Mexican Central Railway from 1896-8, at which time he became mechanical expert for the Galena Signal Oil Company. He served them not only in the United States, but also England and France. In 1902 he became superintendent of the motor power and electric plant of the System Railways, Savannah, Ga., and later on, mechanical superintendent of the Gulf, Colorado & Santa Fe Ry. Co. and the Kansas City Southern Railway Co., Pittsburgh, Kan. From 1906 to the time of his death, he was in business for himself as consulting engineer specializing in railroad work, and editorial writer for engineering publications.

Edmond Fouche

We have learned with great sorrow that M. Edmond Fouche died suddenly at his home in Paris, on Feb. 24.

M. Fouche was president of the Chambre Syndicale de l'Acetylene et de la Soudure Autogene from 1922.

M. Fouche was also president of the Institut de Soudure Autogene, and this charge conferred on him the presidency of the Managing Council of the Ecole Superieure de Soudure Autogene of which he had agreed to be the first manager.

He was chosen by the Compagnie Francaise de l'Acetylene Dissous, in 1896, to manage the studies and practical application of the systems developed by Claude and Hesse. In this work he had as partners Charles Picard and Armand Janet. He investigated all the possible uses of dissolved acetylene, and was particularly interested in the high temperature produced by mixtures of acetylene and oxygen. This led to the first oxy-acetylene blowpipe, working with acetylene under high pressure, conceived by Fouche and Picard.

Two years after, M. Fouche invented the blowpipe with acetylene under low pressure, which bore his name for a long time and bears it even now in numerous foreign countries; from it have been derived all the oxy-acetylene blowpipes now in use. This oxy-acetylene blowpipe for low pressures suggested to him the idea of the hydraulic valve which would hold up the backward flow of oxygen to the acetylene generators.

At a meeting of the Executive Committee of the American Welding Society held in the Engineering Societies Building, New York City, on the 7th day of April, 1931, the following resolution was unanimously adopted:

Whereas: The members and officers of the American Welding Society have learned with deep regret of the untimely death of their Honorary Member, Edmond Fouche, and

Whereas: M. Fouche was a pioneer in the art of fusion welding, and through his natural ability had attained a world-wide reputation as a scientist and engineer, and

Whereas: Not only is the present generation benefited greatly from his achievements, but likewise will future generations appreciate his accomplishments and benefit therefrom, be it therefore

RESOLVED: That the members of the Executive Committee of the American Welding Society on behalf of the members hereby express their deep regret and sense of loss in the death of Edmond Fouche, and their appreciation of his services to the scientific and engineering world, and further be it

RESOLVED: That these Resolutions be spread upon the records of the Society and that copies be sent to his family, to the association with which he was affiliated and to the French Ambassador.

Officers of American Welding Society

At the annual meeting of the Society the following officers and directors were declared elected for the ensuing year:

President—E. A. DOYLE, New York, N. Y.

Senior Vice-President—F. P. MCKIBBEN, Black Gap, Pa.

Divisional Vice-Presidents

Pacific Coast Division—W. A. F. MILLINGER, Los Angeles, Cal.

Southern Division—H. C. PRICE, Bartlesville, Okla.

Directors at Large

A. M. CANDY, East Pittsburgh, Pa.
J. H. DEPPELER, New York, N. Y.
E. H. EWERTZ, New York, N. Y.
A. E. GAYNOR, New York, N. Y.

SECTION ACTIVITIES

LOS ANGELES

The regular monthly meeting of the Los Angeles Section was held on April 14. Mr. Nyquist brought up the question of the adoption of a regular set of by-laws for the Los Angeles Section and submitted a sample set-up. The Secretary was requested to look into the matter and report at the next meeting. After dinner, C. W. Cooper, of the Babcock & Wilcox Company, presented some interesting facts regarding the development of a method for examining welds by X-ray. Following this talk, Mr. Hunt and Mr. Rosenberg demonstrated the Warner electric welding torch. After this demonstration the remainder of the moving picture covering the manufacture of steel tubular products was shown and the meeting was adjourned.

NEW YORK

A joint meeting of the local sections of the American Welding Society, the American Society of Civil Engineers and the American Water Works Assn., will be held on the evening of June 9 at 8 p. m., daylight saving time, in the Engineering Societies Building, New York.

Three important papers are scheduled including bronze welding of cast iron pipe, arc welding of large diameter water pipe and the use of resistance welding in the manufacture of pipe. This is to be the last and one of the feature meetings of the year.

The New York Section of the American Welding Society has arranged for an inspection trip to the Brooklyn Navy Yard (Cumberland Street Gate on Flushing Avenue) on Saturday, May 23, 1931, at 2 p. m. sharp, to observe the increased use of structural welding in naval construction and inspect the following: All-welded seaplane wrecking derrick, 90-ton hull, 110 ft. long, self propelled, just launched; U. S. S. New Orleans, 10,000-ton treaty cruiser, 558 ft. long, 6000-ton hull, about 25 per cent to be welded, recently started; miscellaneous welding operations in various shops, including the Navy Welding School. Exhibition of both gas and arc welding used in naval construction. Program for this event has been arranged by courtesy of Captain James O. Gawne, C. C., U. S. N.

NORTHERN NEW YORK

The Northern New York Section held a meeting April 17 at the Pittsfield Works of the General Electric Company. At 2:00 p. m. an inspection trip was made through the works to see different applications of welding processes. Dinner was served in the Works Restaurant at 6:30 p. m., followed by the meeting in the Works Auditorium at 8:00 p. m.

William Schenstrom, of the Electric Welding Company of America, presented a paper on the electric welding of steel structures.

Mr. Kent, of the same company, also showed lantern slides of welded structures giving details of construction. Views showing the progress of construction of the new welded building at the Pittsfield Works were also shown.

About ninety members and guests attended this meeting.

The following is a list of the officers of the Northern New York Section for the ensuing year:

OFFICERS FOR 1931-1932

Chairman

V. J. CHAPMAN—G. E. Company, Schenectady, N. Y.

First Vice-Chairman

O. A. TILTON—G. E. Company, Schenectady, N. Y.

Second Vice-Chairman

R. T. GILLETTE—G. E. Company, Schenectady, N. Y.

Secretary

F. M. JEFTS—G. E. Company, Schenectady, N. Y.

Treasurer

S. MARTIN, JR.—G. E. Company, Schenectady, N. Y.

Directors

L. D. MEEKER—Term expires 1932—G. E. Company, Schenectady, N. Y.
M. UNGER—Term expires 1932—G. E. Company, Pittsfield, Mass.
T. R. LAWSON—Term expires 1933—Rensselaer Polytechnic Institute, Troy, N. Y.
V. J. CHAPMAN—Term expires 1933—G. E. Company, Schenectady, N. Y.
J. H. MARTIN—Term expires 1934—G. E. Company, Schenectady, N. Y.
F. A. HAUGHTON—Term expires 1934—G. E. Company, Schenectady, N. Y.

Director at Large

A. VOGEL—G. E. Company, Schenectady, N. Y.

PHILADELPHIA

At the annual meeting of the Philadelphia Section held on April 20 the following officers were elected:

Chairman—L. H. CHRISTENSEN, Reid-Avery Company.
Vice-Chairman—CHARLES M. RUSK, R. D. Thomas & Co.
Secretary—H. E. HOPKINS, 709 West Huntington St.
Treasurer—R. D. THOMAS, R. D. Thomas & Co.

J. A. Davies, of the South Philadelphia Works, Westinghouse Electric & Mfg. Co., gave a talk on "Welding as Applied to Marine Equipment."

The May meeting will be held on the 18th at 8:00 o'clock in the auditorium of the Engineers' Club, 1317 Spruce Street. J. W. Meadowcroft, of the Edward G. Budd Manufacturing Company, will talk on "Manufacturing All-Steel Automobile Bodies." Mr. Meadowcroft will illustrate his talk with a motion picture and will have a lot of interesting things to tell of his experiences while in France.

PITTSBURGH

The Pittsburgh Section of the American Welding Society and the Heating and Piping Contractors National Association held a joint meeting on April 22, in the Union Club at which two interesting papers were presented on pipe welding. The first speaker was John H. Zink, president, Heat & Power Corporation, Baltimore, Md., who presented a paper entitled "Recent Developments in Welding Piping." Mr. Zink, who spoke extemporaneously, discussed the design of welded pipe joints, best methods of welding pipe lines, the relation of the pipe welding contractor to the manufacturer of welding equipment, the cost of a welded pipe line as compared with screwed fittings, and he also described interesting tests that he has been conducting. He used many slides and quoted actual data to support the points that he made during his talk.

The second paper was presented by L. Geneski, engineer, Baker-Smith Company, Pittsburgh, Pa., who read a paper on "Welded Heating Installation, Allegheny General Hospital." Approximately 1500 welds will be required on this job, which is the largest welded pipe line installation so far made in the Pittsburgh district. Mr. Geneski described some of the problems met and how they were solved.

The meeting was attended by over 100 men interested in pipe welding. That they were interested is evidenced by the fact that the discussion lasted until 12:45, when the meeting had to be adjourned for Mr. Zink to catch a train for New York, where he had to present a paper the following day before the Annual Meeting of the American Welding Society.

For the May meeting, it is planned to hold a joint session with the University of Pittsburgh and Carnegie Institute of Technology.

EMPLOYMENT SERVICE BULLETIN

SERVICES AVAILABLE

A-130. Graduate M. E. Graduate student training course with Westinghouse Company. Also was connected with welding sales of that company. Spent three months in Europe studying welding and obtaining special training in the process of manufacturing coated electrodes. Had one year contract with another company to reorganize their welding department. Supervised all welding of tanks, containers, pipelines and experimental apparatus for various chemicals.

A-131. Position desired as General Manager, Sales Manager or General Superintendent, by Executive with seventeen years of exceptional broad experience in the General Plate Fabricating, Tank, Sheet metal, Pressed Steel, Structural Steel and the Machine Shop Field. Has thorough knowledge of modern production, cost, designs, estimating, buying and sales. Graduate engineer.

POSITIONS VACANT

V-51. Wanted—First class gas and electric welder. Must be thoroughly experienced in welding aluminum, monel metal, allegheny, etc., in addition fully familiar with welding various types of steel and plate construction. Will eventually take complete charge of welding department.